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THESIS

OPTIMIZING GROUND BASED AIR DEFENSE IN SUPPORT OF HOMELAND DEFENSE: THE CRUISE MISSILE THREAT

by

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Since the attacks of September 11th, 2001 involving commercial aircraft used as missiles to attack critical assets located within the United States, the U.S has worked diligently to enhance its military air defense posture. Air defense of critical U.S. assets and National Special Security Events (NSSE) have been enhanced by adding static and proposed deployable Ground Based Air Defense (GBAD) systems designed to provide a "last line" of defense from air attacks over U.S. soil. Currently this last line of defense is incorporated with the air and maritime military air defense forces providing a "defense in depth" over critical assets, but does not support the air and maritime air defense over broader ranges of U.S. soil where critical assets do not exist. As the U.S. continues to enhance its air defense posture around critical assets and high priority events against terrorist attacks from the air, it is reasonable to assume that the terrorists may adjust their strategy for air attacks. The terrorists may deem it more beneficial to attack targets which lack a last line defense. It is therefore critical to examine new means and methods to provide GBAD in areas which may be determined to be less lucrative targets. In addition to the proposed alternate terrorist strategy, it is also reasonable to assume that increased security measures in the Transportation Security Administration (TSA) will deter the terrorists from attempting another hijacking event; thus forcing them to seek other means of attack. Cruise missiles (CM) are a cheap and effective means of causing limited destruction. Cruise missiles can be programmed to maneuver and operate at various altitudes and are small enough to be transported with little to no visibility. A cruise missile in the wrong hands could find its way to within miles of the U.S. borders and coastlines. If launched; a cruise missile could engage random targets throughout the U.S., such as malls or schools, and cause a major upset to our national security. Therefore, a defense system should be established which incorporates GBAD that is capable of engaging the CM threat with little to no notice, over the entire U.S. border and coastal regions.

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OPTIMIZING GROUND BASED AIR DEFENSE IN SUPPORT OF HOMELAND DEFENSE: THE CRUISE MISSILE THREAT

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ABSTRACT

Since the attacks of September 11, 2001, involving commercial aircraft used as missiles to attack critical assets located within the United States, the U.S has worked diligently to enhance its military air defense posture. Air defense of critical U.S. assets and National Special Security Events (NSSE) have been enhanced by adding static and proposed deployable Ground Based Air Defense (GBAD) systems designed to provide a “last line” of defense from air attacks over U.S. soil. Currently this last line of defense is incorporated with the air and maritime military air defense forces providing a “defense in depth” over critical assets, but does not support the air and maritime air defense over broader ranges of U.S. soil where critical assets do not exist. As the U.S. continues to enhance its air defense posture around critical assets and high priority events against terrorist attacks from the air, it is reasonable to assume that the terrorists may adjust their strategy for air attacks. The terrorists may deem it more beneficial to attack targets which lack a last line defense. It is therefore critical to examine new means and methods to provide GBAD in areas which may be determined to be less lucrative targets. In addition to the proposed alternate terrorist strategy, it is also reasonable to assume that increased security measures in the Transportation Security Administration (TSA) will deter the terrorists from attempting another hijacking event; thus forcing them to seek other means of attack. Cruise missiles (CM) are a cheap and effective means of causing limited destruction. Cruise missiles can be programmed to maneuver and operate at various altitudes and are small enough to be transported with little to no visibility. A cruise missile in the wrong hands could find its way to within miles of the U.S. borders and coastlines. If launched; a cruise missile could engage random targets throughout the U.S., such as malls or schools, and cause a major upset to our national security. Therefore, a defense system should be established which incorporates GBAD that is capable of engaging the CM threat with little to no notice, over the entire U.S. border and coastal regions.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ABBREVIATIONS AND ACRONYMS

AAMDC	Army Air and Missile Defense Command
ABT	Air Breathing Threat
AD	Air Defense
AMD	Air and Missile Defense
ASCM	Anti-Ship Cruise Missile
ATEC	Army Test and Evaluation Command
AWACS	Airborne Warning and Control System
CAL	Critical Asset List
CENTCOM	Central Command
CIA	Central Intelligence Agency
CID	Combat Identification
CIP	Combat Identification Protection
CM	Cruise Missile
CMD	Cruise Missile Defense
CNN	Central News Network
C2	Command and Control
CONOPS	Concept of Operations
CONUS	Continental United States
DAL	Defended Asset List
D-JADOC	Deployable – Joint Air Defense Operations Center
D-HACMD	Deployable-Homeland Air and Cruise Missile Defense

DoD	Department of Defense
ESR	Electronic Surveillance Radar
EUCOM	European Command
FAA	Federal Air Aviation
FBI	Federal Bureau Investigation
FOC	Fully Operation Capable
F/W	Fixed Wing
FWC	Future Warfare Center
GBAD	Ground Based Air Defense
GCC	Global Combatant Command
GWOT	Global War on Terrorism
HACMD	Homeland Air and Cruise Missile Defense
HLD	Homeland Defense
HLS	Homeland Security
HMMWV	High Mobility Multi-purpose Wheeled Vehicle
IAMD	Integrated Air and Missile Defense
IFF	Identify Friend or Foe
JADOC	Joint Air Defense Operations Center
JADO-H	Joint Air Defense Operations – Homeland
JLENS	Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System
JTAMDO	Joint Theater Air and Missile Defense Organization
JT&E	Joint Test and Evaluation

LACM	Land Attack Cruise Missile
LCI	Low Cost Interceptor
MDA	Missile Defense Agency
NASAMS	Norwegian Advanced Surface to Air Missile System
NORTHCOM	Northern Command
NORAD	North American Aerospace Defense Command
NSSE	National Security Special Event
NTSB	National Transportation and Safety Board
OIF	Operation Iraqi Freedom
PACOM	Pacific Command
PCL	Passive Coherent Location
PID	Positive Combat Identification
PK	Probability of Kill
POTUS	President of the United States
RADS	Regional Air Defense Sectors
ROTHL	Relocatable Over-the-Horizon Radar
SAM	Surface to Air Missile
SEDP	System Engineering and Design Process
SIAP	Single Integrated Air Picture
SLAMRAAM	Surface Launched Advanced Medium Range Air to Air Missile
SMDC	Space and Missile Defense Command
TOI	Tracks of Interest
TSA	Transportation Security Agency

USCG	United States Coast Guard
VID	Visual Identification
VWC	Virtual Warfare Center
WAS	Wide Area Surveillance

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I. INTRODUCTION

A. BACKGROUND

One of the major challenges that the U.S. faces today is recognizing the necessity to restructure the homeland missile defense posture. It is logical to assume that current missile defense programs, in concept, are adequate to counter any long range threats from North Korea or Iran, but what is less obvious is the necessity to design a program to engage a more irregular threat such as Cruise Missiles (CM's) which could potentially be launched from near-by borders or sea shores.

The post 9-11 United States has been challenged to recognize new perceptions of threats to homeland security. Following the break up of the Soviet Union, much of the technology, expertise and in some cases the raw material necessary to create hostile missile systems, have found their way into the hands of state and non-state actors whose ultimate goals for the use of such technology may threaten U.S. interests and our national security. One aspect of the American defense posture which did not change with the collapse of the Soviet Union was our doctrine concerning threats from the air. U.S. planners, as well as citizens in general, had become complacent in the idea that air attacks could only be executed from distant areas, and that our military sensors and defensive systems were adequate to counter such a threat.

The necessity for a defense against threats from the air was proven on September 11, 2001 when short range friendly (to clarify; friendly in this context refers only to the fact that the aircraft could not be identified as enemy aircraft) air attacks became a viable tactic for our enemies and exposed a weakness in our defensive barriers. In particular there were no Ground Based Air Defense (GBAD) systems in place which could have served as a "last resort" line of defense against the hijackers. To be certain there were plenty of Air assets which were quickly scrambled by order of the North American Aerospace Defense (NORAD) Command, but their efforts, while noble, were not effective in

preventing the destruction of a portion of the Pentagon and the two World Trade Centers. "Exercise planners assumed that the aircraft would originate from outside the United States, allowing time to identify the target and scramble interceptors… the threat of terrorists hijacking commercial airliners within the US- and using them as guided missiles- was [SIC] not recognized by NORAD before 9/11."[1] Communications between organizations and defensive operating systems were virtually non-existent, and what little military response was only rendered from U.S. military aircraft. Doctrinally, there was no Ground Based Air Defense (GBAD) mandated to respond to this type of threat.

U.S. policy makers and citizens are in a critical state of emergency with regards to national security. The time has come to review five decades of cold war defense posturing designed to deter and negate global strategic threats which were distant and visible, and incorporate the proper doctrine to defend against asymmetric threats from both state sponsored authoritarian regimes capable of mass destruction and small decentralized terrorist cells capable of planning autonomous, small scale-grand effect-attacks on U.S. soil. Converting our national defense from a cold war posture to counter the modern asymmetric threat requires much more than revamping policy and rethinking strategy; it requires a complete retooling of both civil and military national infrastructure. New and more sophisticated technology will be required to prevent, detect and defend against short, medium and long range threats. There exists a need to improve our current weapons sensor and shooter capabilities.

It is our position that a properly placed GBAD asset such as the U.S. Patriot or Avenger/Stinger units could have served as a last line of defense from an air threat over U.S. soil and could have, at best, minimized the loss of life on the ground. GBAD concepts and doctrine can eliminate confusion in an otherwise confused combat environment. Certain safe guards such as restricted and no-fly zones, as well as Identify Friend or Foe (IFF) codes and visual identification enable ground units to decipher enemy targets for possible engagement. In the

[1] 9/11 Commission Report 17.

case of 9-11, had a restricted zone been established around those critical areas, anything flying in the designated airspace may have been engaged over water or less densely populated areas by GBAD assets. Of course air defense of the U.S. is not limited to just Air Breathing Threats (ABT)'s such as that on 9-11, but also to the possible future defense against threats such as low grade CM's.

B. PROBLEM

The U.S. faces a new threat to its own national and border security. The new enemy is innovative, adaptive and is not constrained by international rules of engagement or political reprisals. This threat has demonstrated its capability to seek out and expose America's security weaknesses through methodical analysis and observation. The enemy counts on U.S. strategy and restrictive policies to enhance their ability to exploit gaps in our national defense posture. In addition the enemy uses our misunderstanding of their capabilities and intent to their advantage in planning and carrying out terrorist attacks. Currently the U.S. assumptions about terrorist tactics are that they will seek to strike well known critical infrastructure targets or popular special events. Their intent in this case would be to cause a mass of casualties and destruction in order to create large scale effects of fear and confusion. Thus current planning for terrorist's attacks from the air assumes that the terrorists will attack only densely populated areas with major financial, military or industrial infrastructures critical to U.S. survivability, or National Special Security Events (NSSE)'s such as the Superbowl or Olympics.

While there are a myriad of Air Force, Naval, Coast Guard and intelligence forces allocated to support homeland defense, those assets are limited in their capabilities to cover every inch of U.S. territory. Furthermore, the U.S. borders and coastlines are expansive and porous. If the combination of those forces should fail to prevent a "leaker" air threat from penetrating U.S. air space there is not an adequate amount of GBAD forces to provide for that critical "last line" of defense.

A couple of problems exist in supporting this last line defense. The first is that the GBAD resources, which are comprised mainly of short, medium, and

high range Surface to Air Missiles (SAM's) such as Patriot, Avenger and SLAMRAAM are assigned primary missions to support their regional and Global Combatant Commands (GCC's) such as Central Command (CENTCOM), European Command (EUCOM) and Pacific Command (PACOM). Northern Command (NORTHCOM) and North American Aerospace Defense Command (NORAD), who have the mission of Homeland Defense and Air Defense against air and CM threats, have a very limited short and medium GBAD capability.

A secondary problem is that the current GBAD systems are designed to provide only point defense of specific critical assets. In other words, those systems can only provide for the defense of specific points such as oil fields, buildings, and ports. This type of defense, if allocated for homeland defense, requires a tailorable, packaged force with a designated mission to protect a specific asset in a designated time frame. This strategy can be supported by designating certain Air and Missile Defense (AMD) units, dispersed throughout Continental U.S. (CONUS) Regional Air Defense Sectors (RADS) to provide GBAD for specific critical assets or National Special Security Events (NSSE), but do not cover areas which are not assigned as critical assets such as schools, malls and other minor metropolitan facilities.

GBAD provides an "in depth" level of air defense that makes targets less desirable to our enemies. Areas without the added GBAD may offer a less than optimal defense design and expose potential seams for terrorists to target. This may present a viable secondary strategy for a terrorist who may be willing to strike smaller and less profound targets in order to prove that they can still attack Americans on U.S. soil thereby shaking the confidence of many Americans in their government's ability to provide for their safety. It is reasonable to predict that an enemy, who believes so deeply in martyrdom, can afford to expend squad size resources to engage less critical and sparsely populated U.S. cities and towns using low grade CM's to strike random targets along our coasts and borders.

The belief that the terrorists will continue to strike large critical infrastructure targets, as well as seek to exploit vulnerabilities in the U.S. defense by striking random low value targets, seem to be viable enemy strategies. It is therefore necessary to examine which strategies are most viable and feasible for the terrorists with regard to cost versus payoff. Accordingly it is critical to examine what may be the best strategy for the U.S. to provide GBAD against one or all of the terrorists most viable strategies.

C. ASSUMPTIONS

There is a need to assume that terrorist organizations will continue to plan future operations that involve the destruction of large industrial, financial, military or otherwise critical U.S. assets in order to cause mass chaos among the American populace. It is likely that these plans may include the use of CM's. It is therefore assumed that the U.S. air defense posture should incorporate measures to mitigate that threat with forces operating in the air, sea and ground. It is assumed that the ground based defensive effort will serve as the "last line" effort in the order of battle or that it will provide coverage where the air and maritime assets otherwise can not. Given the expansive borders of the U.S., it can be assumed that the GBAD designated for defense should be robust, rapidly deployable and tailored to mission requirements to provide *point defense* of such critical assets.

There is also a need to assume that the terrorist will seek to analyze current U.S. efforts to defend against attacks against their larger industrial complexes and that there may be little payoff in time, money and energy in planning such attacks versus their ability to be successful in executing them. It is likely that terrorists could seek to destroy softer targets which are not afforded adequate air defense resources such as random towns, schools or malls. In Operation Iraqi Freedom (OIF) I, Iraqi militants launched several Ababil-100, and Al Samoud missiles toward its own Southern region and Kuwait. After realizing that their high value targets were well defended by U.S. and Kuwaiti Patriot Missile defenses, they launched one successful strike at a soft target. According to a CNN report dated March 29, 2003, an Iraqi FAW-200, or seersucker cruise

missile impacted the Souq Sharq Mall where civilians were shopping and attending movies. The attack was executed without detection from friendly forces and thus, no alarm was sounded prior to engagement. The report went on to quote the Kuwaiti Information Minister, Ahmad Fahd al-Sabah as stating "This kind of missile usually it [SIC] flies between 20-25 meters [66-83 feet] over the land. For that, there is no defense system that can reach it. The Minister went on to note that there were three versions of the FAW which were capable of engagements as far as 143 miles from its intended target."[2] Therefore, it is reasonable to assume that an adaptive enemy may choose this exact same tactic to launch an attack undetected within the borders of Mexico, Canada, or from a vessel outside of our coast lines at a non-specified target. Thus there remains a need to develop and incorporate a GBAD system capable of defeating such a threat; one that can provide *area defense* of entire regions in addition to specific critical assets.

We recognize that there are several components of homeland security and homeland defense of equal and perhaps greater importance. That being said the purpose of this thesis will focus solely on homeland defense rather than homeland security; we will be focusing only on cruise missile threats to U.S. soil. In order to clarify the narrow focus of our study it is important, first, to distinguish the difference between homeland security and homeland defense since the two terms can seem synonymous. Homeland Security, as defined in the National Strategy for Homeland Security, is "a concerted national effort to prevent terrorist attacks within the United States, reduce America's vulnerability to terrorism, and minimize the damage and recovery from attacks that do occur." The Department of Homeland Security is the lead Federal agency for homeland security. In addition, its responsibilities extend beyond terrorism to preventing, preparing for, responding to, and recovering from a wide range of major domestic disasters and other emergencies. The definition of Homeland Defense is: The protection of United States territory, domestic population, and critical defense infrastructure

[2] CNN.com/World *Missile Hits Kuwait City Mall*. Saturday March 29th 2003. Retrieved on 4 October 2006, from http://www.cnn.com/2003/WORLD/meast/03/28/sprj.irq.kuwait.explosion/index.html.

against external threats and aggression. It also includes routine, steady state activities designed to deter aggressors and to prepare U.S. military forces for action if deterrence fails.[3]

Simply put, the mission of homeland security is primarily conducted by the civil services; Police, FBI, CIA, NTSB etc… Their job is to use intelligence and police actions to seek out and defeat the threat before it is effectively operational. The role of homeland defense is primarily a military one conducted in concert with all branches of service. Their job is to prepare to defend the homeland when security measures have failed to detect a threat that is now imminent. Both of these elements work together in the realm of intelligence sharing and also consequence management in the event that a terrorist attack is completed. In addition the U.S. military can be called to assist civil services humanitarian efforts. The role of GBAD is a very small, but important function of homeland defense. In the worst case scenario however, properly placed GBAD can serve a most critical function as a final line of defense.

D. THESIS

The impetus for this thesis will be to make clear that the current U.S. air defense posture can be enhanced by using GBAD systems to provide a multi tiered, "defense in depth" designed to support and optimize the abilities of current air and maritime resources designated for homeland defense. This thesis will focus on threats which originate from outside of our borders and coastlines which intend to launch short range attacks using CM's and non-conventional tactics. We will demonstrate that the terrorists will alter their strategy of attacking large critical targets and events in order to enhance their probability of success versus payoff. Thus, we will demonstrate the need to implement a GBAD system capable of reacting quickly to, and successfully engaging a "no notice" CM attack. Rather than inventing a new technology, we seek to optimize what resources are already in operation or emerging in concept.

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[3] Department of Defense, *Strategy for Homeland Defense and Civil Support*, Washington, D.C., .June, 2005. p. 10, Retrieved 3 September 2006 from http://www.fas.org/irp/agency/dod/homeland.pdf#search=%22strategy%20for%20homeland%20defense%20and%20civil%20support%22

E. METHODOLOGY

In the ensuing chapters we examine the methods and process necessary to optimize GBAD in support of homeland defense. Using the Systems Engineering and Design Process (SEDP), we identify and define the problem that currently exists; identify the stakeholders; conduct a needs analysis; and identify alternatives for the current U.S. air defense posture. We use game theory to examine two strategies terrorist may use to employ threats from the air, and two strategies the U.S. may deem feasible to counter those threats.

We analyzed current weapons systems which are designed to intercept CM's, and review the current strategy and policies for homeland defense against air and missile threats. We also assessed the role of GBAD in the layered defense posture in countering threats from the air. We assessed the GBAD role as it stands currently and investigated future plans to enhance air and missile defense, and proposed recommendations that will optimize the U.S. air defensive capabilities.

Our research examined the Concept of Operations (CONOPS) for the defense of critical assets, as well as that of the general populace, to determine optimal placement of weapons systems and forces. We looked beyond what systems are currently funded for Homeland Air and Cruise Missile Defense (HACMD) and interviewed engineers involved in the future warfare and technology battle labs, in order to determine the available depth of assets and resources available for HACMD.

We looked at the current force structure to assess the strength and capabilities to deploy GBAD forces in support of the CAL\DAL. Providing rapidly deployable air and missile defense forces throughout the several CAL's in the U.S. requires the availability of assets with a designated mission with predetermined coordinates who are well rehearsed through the process of battle drill exercises and deployments.

Our analysis also looked at the long and short range capabilities of our current GBAD weapons systems and examines the effectiveness of those

weapons in testing and evaluations. We sought out emerging concepts and technologies such as the Low Cost Interceptors (LCI)'s which may provide a static long term defense across all of our borders and seaboards. Such technologies and systems may be available at low cost to the force provider. In addition to lower cost, these systems could also provide an element of security that is less obtrusive to the civilian populace.

Our resulting data analysis is intended to provide a general recommendation to the public for optimizing Ground Based Air Defense systems, and personnel to support Homeland Defense in its war against terrorist aggression from the air. Our recommendation will be based on our research and is not intended to formulate policy, but rather to identify an issue and provide recommendations and viable alternatives.

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II. NEEDS ANALYSIS

A. IDENTIFIED NEED

The post 9-11 U.S. has made tremendous strides in improving communications and information sharing among the intelligence agencies. The establishment of the Department of Homeland Security (HLS) and the stand-up of Northern Command (NORTHCOM), has demonstrated the value that our government has placed on our security. The National Transportation and Safety Board (NTSB) and Transportation Security Agency (TSA) have excruciatingly improved security measures at all U.S. airports. While these steps have not been in vain, they can be viewed as merely a palliative to the American people from the reality of the terrorist threat. The current HLD strategy for defense against air threats focuses more directly toward the type of attack that has already occurred and does not focus enough effort on what new type of air attacks may be viable for terrorists.

This mentality is based on an assumption that the terrorist are myopic in their strategy and have limited imagination and resources. The more obvious point is that the attacks of 9-11 were successful because the terrorist had spent years studying where the U.S. was not focusing its security efforts. Thus, in determining a successful defensive strategy to protect U.S personnel, infrastructure and forces from enemy asymmetric air attacks, there is a need to evaluate which military systems can provide for the best defense of probable targets such as critical assets as well as the general U.S. populace.

In assuming that terrorists may not seek to use the same strategy of attack, by using hijacked aircraft, we should also assume that they may seek to explore a different style of weapon. If our assumption -that hijacking an aircraft is no longer a viable option for terrorists- is true, the aircraft may no longer be their weapon of interest. The modern cruise missile presents a viable alternative as a

weapon that has the capability of engaging the U.S. populace, critical infrastructure and forces on our own soil, from distances well outside of our borders and coastlines.

In recognizing the need to establish a viable defense system against a CM threat, it is critical to evaluate and analyze what type of assets terrorists may wish to target. Common thought dictates that terrorists wish to attack high value targets which are representative of American culture. More to the point however, is the fact that the lasting effects of destroying major economic, information, military and energy facilities has a far greater impact than that of the destruction of the facility itself. Therefore, critical assets and infrastructure will continue to have priority in the defensive order of battle and national defense resources. In 2002 the Department of Defense released an executive report regarding the importance of protecting critical U.S. infrastructure stating "The need to protect critical infrastructure is recognized at the highest levels of the National Command Authority. The President of the United States, the Secretary of Defense, and the Chairman of the Joint Chiefs of Staff have all published detailed guidance requiring the Defense community to establish effective programs for such a protection. But even without directives requiring formal CIP programs, protecting critical assets is an obvious fundamental requirement for all defense activities. In conventional wars, critical assets have always been considered lucrative targets. They become even more so in an asymmetric conflict where small unconventional forces seek to inflict maximum damage with minimal resources."[4]

Another important issue concerning national defense planners is the ability to provide for the common defense of all U.S. citizens. The idea that every American citizen should feel protected at home and in our daily lives is written in our constitution. "We the People of the United States, in order to form a more perfect Union, establish justice, and ensure domestic tranquility, provide for the common defense… establish this Constitution for the United States of America."[5]

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[4] Department of Defense. *Critical Infrastructure Protection*, Executive Report 2002.

[5] Preamble to the United States Constitution. Retrieved on 16 November 2006 from http://en.wikipedia.org/wiki/preamble_to_the_united_states_constitution

While logic dictates that the destruction of critical assets can negatively impact a greater percentage of the populace than the destruction of an isolated segment of society with no economic outreach, a successful strike of such a segment could damage the confidence of the U.S. citizens and their faith in the government to provide for their protection against all foreign threats.

It is clear that there is a need for the U.S. to consider a line of defense that is capable of engaging cruise missile threats which may elude both air and maritime defense forces. This “last line” of defense needs to be capable of defending the U.S. civilian populace and U.S. critical infrastructure, as well as provide force protection from irregular air strikes on U.S. sovereign territory. Our efforts here focus on the need for a defense from a CM threat, which has evaded detection and engagement from the current system in place, designed to engage such threats. All criteria evaluated in the analysis are thus subjected to an assumption of a failure in existing systems to defeat such a threat, not a presumption of such failure.

B. THE CRUISE MISSILE THREAT

CM’s present a more unique threat than conventional aircraft because they are fast, low flying and maneuverable. Most threats from the air are detected by ground based radar sensors looking up. Cruise missiles have the ability, not only to fly below the scope of these radars, but also the ability to maneuver around natural and urban terrain. Defense from this type of threat requires the use of sensors with the ability to look down and around wide areas. What is even more daunting is the ability of non-state actors to acquire and transport CM’s with relative ease. “Cruise missiles are cheaper to build and buy than ballistic missiles, making them attractive to countries with less advanced militaries and to non-state actors as well. Tracking proliferation of cruise missiles is difficult because the materials and technology involved have multiple uses. They are also easy to hide and transport/relocate because of their smaller size. Once launched, these low-flying missiles are especially difficult to detect/engage in the clutter of ground objects. The restrictions of line-of-sight, due to the earth’s curvature, on surface-based sensors also make detection and engagement

extremely difficult; that is, a low-flying CM cannot be seen until it breaks the sensor's horizon, usually at close range.[6]"

Specifications of the CM are not the only attributes that make them attractive to terrorists. Our own fortification of critical U.S. assets will likely make CM's more appealing to the enemy due to our over emphasis on countering a slower moving threat from a higher elevation. "Cruise missiles have a number of characteristics that make them desirable as weapons; the dominance of US air forces and the emphasis on US ballistic missile defenses may further increase their attractiveness. As a result, the United States and its allies are likely to face a growing cruise missile challenge, from their employment in a future regional contingency to their use by terrorists against the US homeland."[7] According to some recent studies converting Anti-Ship Cruise Missiles (ASCM) into Land Attack Cruise Missiles (LACM) can be done fairly easily with off the shelf technology and modest foreign assistance used to enhance the CM guidance and propulsion systems. Iraq's Al Faw CM system, which was responsible for the 2003 attack on a Kuwaiti mall, was one such endeavor. It is believed that with substantial foreign help, that Iran could convert its silkworms into LACM's in the next three to five years.[8]

C. STAKEHOLDERS ANALYSIS

The current stakeholders in the concern for defense from CM attacks are the same as the overall stakeholders in the Global War on Terror (GWOT). The Department of Defense (DoD) has overall responsibility for the protection of U.S citizens and infrastructure. Responsibility for carrying out the planning and operational side of CM defense is divided among several agencies.

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[6] National Security Watch. "The Cruise Missile Threat: Prospects for Homeland Defense." The Institute of Land Warfare; Association of the United States Army. 2425 Wilson Blvd Arlington, VA 22201. NSW 06-03. 2. 1 June 2006.

[7] Thomas G. Mahnken. *The Cruise Missile Challenge*. Center for Strategic and Budgetary Assesments. March 2005, 2-3. www.csbaonline.org

[8] Ibid., 26-27.

1. Agencies

a. NORTHCOM

NORTHCOM is responsible for conducting operations to deter, prevent and defeat threats and aggression aimed at the U.S. its territories, and interests within the assigned area of responsibility. NORTHCOM, at the request of the President of the United States (POTUS) or Secretary of Defense (SECDEF) can provide military assistance to civilian agencies for consequence management.[9]

b. NORAD

NORAD had two primary missions: 1) Aerospace Warning- monitor man-made objects in space and detect, validate and warn of attack against North America, and provide Integrated Tactical Warning and Attack Assessment (IT/WAA) to U.S. and Canadian Governments. 2) Aerospace Control- provide surveillance and control of North American airspace. Detect identify, monitor and if necessary take appropriate action against manned or unmanned air-breathing vehicles approaching North America.[10]

c. JTAMDO

Joint Theater Air and Missile Defense Organization (JTAMDO) is chartered to plan, coordinate, and oversee Joint Air and Missile Defense (AMD) requirements, joint CONOPS, operational architectures, and development of the Joint Integrated Air and Missile Defense (IAMD) roadmap. They are responsible for evaluating systems and emerging technologies… to counter aircraft, cruise missile and ballistic missile threats.[11]

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[9] NORAD J-5 "Future Concepts and Capabilities" Power Point Brief dated 18 January 2006.

[10] Ibid.

[11] JOINT STAFF FY 2005 Budget Estimates Research, Development, Test, and Evaluation (RDT&E), Defense-Wide Exhibit R-2, RDT&E Budget Item Justification. February, 2004.

d. MDA

Missile Defense Agency (MDA) mission is to "Develop and field an integrated BMDS capable of providing a layered defense for the homeland, deployed forces, friends, and allies against ballistic missiles of all ranges in all phases of flight."[12]

e. SMDC

Support for Joint Testing and Evaluation of HACMD and Deployable HACMD (D-HACMD) is the responsibility of the Space and Missile Defense Command (SMDC), Future Warfare Center (FWC), Army Test and Evaluation Command (ATEC).

f. 32nd/263rd AAMDC

Responsibility for the operational side of GBAD in support of HACMD was initiated by the 32nd Army Air and Missile Defense Command (AAMDC), and is currently transferring responsibility to the National Guards' 263rd AAMDC.[13] All of these organizations are working diligently to combine all of their HACMD resources into one cooperative family of sensors and shooters.

2. Service Systems and Responsibilities

a. Army

The Army is the lead service for development of a ground-based defense against air-breathing threats, including aircraft and missiles:

• The Patriot Capability 3 (PAC-3) missile, used during Operation Iraqi Freedom, can intercept and destroy incoming cruise and ballistic missiles. An extended-range version of the PAC-3 interceptor is under development. PAC-3 defense is limited to relatively small areas, or point defenses.

• The Medium Extended Air Defense System (MEADS), jointly undertaken by the American, German and Italian militaries, will be operational in

[12] Missile Defense Agency Mission Statement retrieved on 19 November 2006 from http://www.mda.mil/mdalink/html/aboutus.html.

[13] Interview with COL Nanette Mueller, Deputy G-3 for Integrated Air and Missile Defense, SMDC, Peterson, AFB, CO. 13 November 2006.

the post-2010 timeframe. MEADS will provide 360- degree surveillance and tracking against airborne and ballistic missile threats. MEADS technology will be integrated into the force(s) as it becomes available. Like PAC-3, MEADS will be limited to small-area or point defenses.

• The Joint Land Attack Cruise Missile Defense Elevated Netted Sensor (JLENS) is an aerial sensor that will detect and identify cruise missiles and other low-flying objects at greater ranges and provide engagement-quality data to shooters. JLENS provides sustainable, long-term tracking and identification, as it can remain airborne for many days at a time at a relatively low cost. This system will combine with PAC-3 and MEADS to greatly increase intercept range, thereby allowing in-depth defense of larger areas.

• The Army's Short-Range Air-Defense (SHORAD) system will also have a role in CMD. SHORAD has the ability to fire surface-to-air missiles (SAMs) from various platforms to engage all air-breathing targets, albeit at very close ranges.[14]

b. Navy

The Navy also has extensive experience in defending against low-flying weapons like cruise missiles. The Aegis Combat System, the E-2C Hawkeye aircraft and the Cooperative Engagement Capability (CEC) make up the Navy's main CMD capability.

• The Aegis Combat System is used primarily in the fleet air and missile protection mode but can provide limited shore-based asset defense.

• CEC is a sensor networking technology integrated on Navy assets to allow the merging of radar data from many different CEC-equipped sources. With the completed installation of CEC in the fleet, all members of battle groups will have an integrated air picture, resulting in enhanced reaction time and weapons performance. Weapons will also be able to engage more quickly and at greater ranges than when they relied on local sensors.

[14] National Security Watch. "The Cruise Missile Threat: Prospects for Homeland Defense." 1 June 2006, 3.

• The airborne E-2C Hawkeye detects long-range, over-the-horizon cruise missiles and directs fighter intercept of the hostile tracks at greater ranges.

These three capabilities combined can provide a comprehensive, single integrated air picture that greatly extends the detection, tracking and engagement of cruise missiles.[15]

c. Air Force

The Air Force traditionally has been the lead in defending the homeland from the air. Today, the Air Force uses surface and airborne sensors data-linked to airborne interceptors and their air-to-air missiles. The fighter interceptors and the Airborne Warning and Control System (AWACS) are the foundation of the Air Force's current CMD capabilities.

• The fighter interceptors carry air-to-air missiles. The F/A-22, the replacement for the F-15, is designed (in addition to other missions) to defend against cruise missiles at home and in forward areas.

• AWACS can provide surveillance data on low-flying objects in the range of most cruise missiles, detect and identify potential threats and interact with fighters to intercept and neutralize the threat.[16]

D. CURRENT GBAD ANALYSIS AGAINST CM

While the prospect of acquiring CM's for an attack against the U.S. may seem to be a viable alternative for terrorists, some experts estimate that the time effort and money that is required to acquire and launch a CM is not worth the ultimate payoff they wish to achieve. For instance, if terrorists wished to launch an attack in a rural area which is not well protected, the amount of destruction they wish to achieve with a CM may be as extensive as using a backpack full of C4, or some home made explosives. There are several steps in the acquisition process that the terrorists would have to go through to gain the proper material for a CM, many of which would not go unnoticed by intelligence assets at home

[15] National Security Watch. "The Cruise Missile Threat: Prospects for Homeland Defense." 1 June 2006, 3.

[16] Ibid

and abroad. If terrorists could obtain the material they would then need to obtain the resources to transport the material which is also difficult to do without being detected. And finally, if the acquisition and transport of the CM were successful, there are several surveillance and security levels the terrorists would have to negotiate to launch a strike.

Captain Fred Midgette, the Department of Homeland Security (DHS), United States Coast Guard (USCG) liaison to NORAD/NORTHCOM, notes that it would be difficult for a non-state actor to acquire a seaborne vessel, because it would have to come by way of a state flagged vessel, and that no country would be willing to run that risk with the U.S. Furthermore, in the option that terrorists may attempt to steal a vessel to achieve their objectives, there would likely be a report filed and they would be an anomaly among or outside the normal commerce shipping lanes. While the DHS USCG LNO deems the possibility of terrorists launching a CM from a sea vessel as unlikely, he does not think it is impossible. Osama Bin Laden's connections to questionable foreign freighter companies could offer opportunities to pose as a bogus shipping company and send a leaker vessel within range of U.S. coastlines. Capt Midgette further stipulates that normal off shore supply vessels would not have the ability to make the journey from overseas. However, a coastal freighter could make the journey from distant countries.[17]

A February 2006 briefing conducted by the Massachusetts Institute of Technology- Lincoln Labs (MIT-LL) assessed several air threat types, and their ability to attack the U.S. Their assessment of the CM attack was that it would be both hard for the terrorists to execute such an attack and that it would be difficult for current U.S. sensors and shooters to defend against such an attack. They assessed the defense of such an attack as moderate to hard due to the CM low radar cross section. The study further examined seven categories of our active defense capabilities in point and area defense: Enhanced Battle Management

[17] interview with Department of Homeland Security (DHS), United States Coast Guard (USCG) liaison to NORAD/NORTHCOM, Captain Fred Midgette, and Commander Enseign, NORAD/NORTHCOM, Peterson, AFB, CO, 14 November 2006.

Command, Control, Communications, Computers and Intelligence (BMC4I); Train for National Cruise Missile Defense (NCMD) Mission; Local air surveillance; Maritime surveillance; Offshore air surveillance; Fast take off armed Unmanned Combat Air Vehicle UCAV; and Air directed Surface to Air Missiles (SAM)/GBAD. The assessment noted that GBAD could provide adequate point and area defense with good active defense identification as being critical.[18]

E. CONCEPT OF OPERATIONS

1. Scheme of Attack

The general scheme of a CM attack consists of rogue actors using non-conventional means to strike an unsuspecting and unwilling participant in an area where they appear to be most vulnerable. A non-state actor or terrorists who may attempt such an air attack on the U.S. can likely presume that they will face a formidable and multi tiered air defense. Therefore we can assume that the terrorists will be forced to create innovative and imaginative techniques for attacking the U.S. and that their weapons will lack sophistication; at least so far as obtaining any traceable or accountable resources and material. A typical scenario may consist of a CM launched from a small sea going vessel.

A non-state actor with connections to illegitimate or bogus overseas shipping companies could acquire a coastal freighter and load it with disassembled raw material components designed to build a CM. The non-state actor could then assign a small group of terrorists to take command of the vessel, infiltrate the crew, or hijack the freighter prior to embarkation. Once in route, the crew may attempt to stay within normal commercial trafficking lanes and run the risk of being detected and interdicted prior to coming within launching range of the U.S. If accurate intelligence, or random searches result in the CM being detected prior to launch, then the terrorist plan is thwarted.

If the terrorists manage to leak through the maritime defenses and begin to come within range of the U.S., they would then need to begin procedures to assemble and launch the CM. If detected during this phase the U.S. military

[18] L.O. Upton, MIT, Lincoln Labs, "Homeland Defense Threat Assessment," Homeland Air Defense Study/ Executive Summary, February, 2006. Slides 6 and 10.

forces could scramble jet fighters and AWACS sensors to defend against the threat by either interdicting prior to launch, or intercepting the CM after the launch. The ability to detect and defeat a CM launch in this phase is greater in areas of the U.S. which already have defended critical assets or around NSSE's. If the terrorists could manage to come within roughly 100 miles of the U.S. coastline, avoiding all methods of detection and engagement from the maritime and air forces, a successful CM launch could provide only minutes for a military force to detect and engage the CM before it strikes U.S. soil.

Given this scenario, the terrorists have a choice in determining which targets may be the most profitable. One may be to conduct an attack similar to that of 9-11 which is designed to disrupt major U.S. operational infrastructure and create mass devastation. A successful operation of this sort could prove to be a high payoff operation for the terrorists, but at an extremely high risk to their probability of success. Another method may be to strike a random target anywhere along the coasts or borders. This type of operation may not provide the same payoff value for the terrorists, but may offer a higher probability of success.

F. FUNCTIONAL ANALYSIS

The concept of defensive operations for U.S. planners should involve the ability for our civil and military forces to, 1) detect the threat and determine its identity; 2) provide a defense against the threat through the use of tactics which may thwart the ability of the threat to continue its mission; and 3) when all other efforts fail, the U.S. should have a capability to defeat the threat at a distance which maintains the safety of the U.S. populace, our critical assets and the force employed to provide the defense. Figure 1 depicts the functional flow of such an operation and how the U.S. can conduct operations to limit the capabilities of the terrorists.

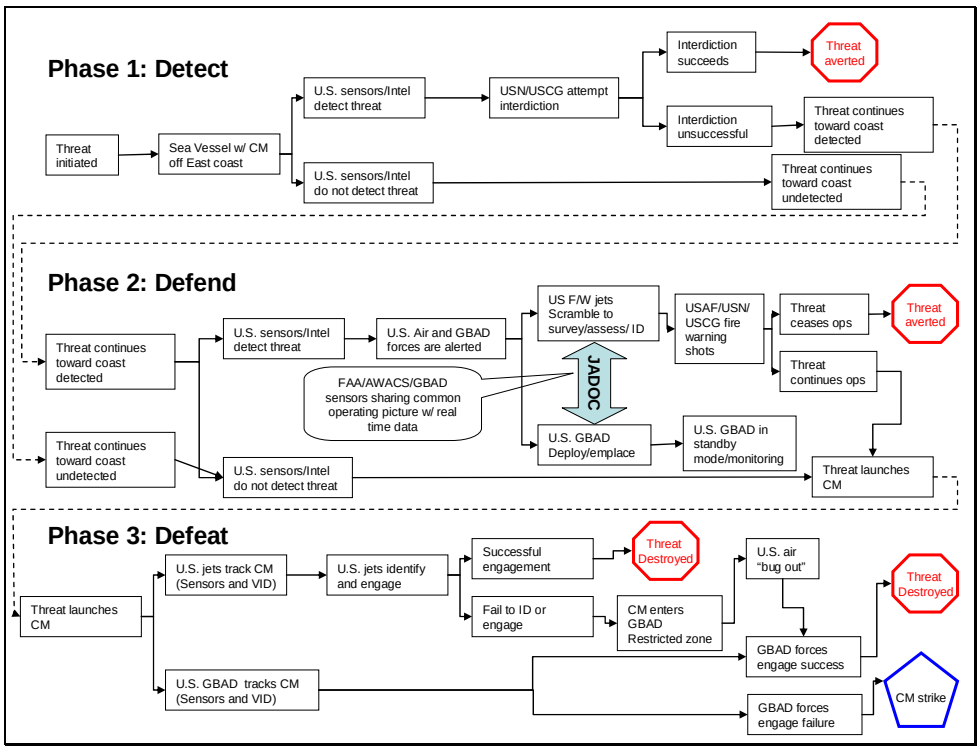

Figure 1. Functional flow diagram of a possible cruise missile strike.

The above chart demonstrates a multi tiered defense scenario where joint military forces are conducting synchronized operations. This scenario also includes an organic "last line" GBAD. GBAD's role is demonstrated in phase three "Defeat", to provide ground based sensor and shooter support in a joint environment. Since this particular defense design is providing support over U.S. soil, the role of GBAD is to be the last resort for engagement against a CM threat; that is when the threat has eluded all other maritime and air combat systems. This differs from the conventional wartime role of GBAD which is to augment and share battle space with other combat operating systems in which "shooters" are tasked to engage targets based on their optimal capabilities and position with regard to the threat.

G. SYSTEM OBJECTIVES

GBAD systems involved in the last line of the "Defeat" phase need to be capable of sharing data with the air and maritime defenses and should be capable of engaging enemy air targets at distances which would reduce or eliminate collateral damage over U.S. interests in order to, 1) protect the lives of

U.S. citizens; 2) protect critical U.S. infrastructure; 3) protect U.S. forces and equipment. The “Defeat” phase is the most sensitive in the order of battle as this is the phase where the threat comes closest to U.S. soil. In order to defeat the threat and reduce the probability of fratricide we have identified four sub-functions which are critical in GBAD operations when attempting to defeat the CM attack.

First the system must be capable of providing a *Wide Area of Surveillance (WAS)* that can detect a threat far enough out to provide timely intelligence about a Track of Interest (TOI). This is critical to ensuring that all agencies monitoring U.S. airspace have situational awareness and the ability to share information which identifies the TOI. Once a TOI is tracked, the system must be capable of obtaining a *Positive Combat Identification (PID)*. This is critical in preventing an accidental shoot down of non-hostile tracks. Additionally, the system should offer a *ready force* capable of deploying and operating CM defense systems in a rapid manner. This issue takes on a different meaning when the combat operations are taking place over U.S. soil. Optimal placement for some GBAD systems may intrude on the privacy of some U.S. citizens. Therefore it is important to optimize the use of government and/or public property which is least obtrusive to the general public. Finally, the system should be *operationally feasible* in order for the system to be successfully employed and operated. The following is a break down of the objectives hierarchies which are necessary to defeat a CM attack:

1. Defeat the Cruise Missile Attack

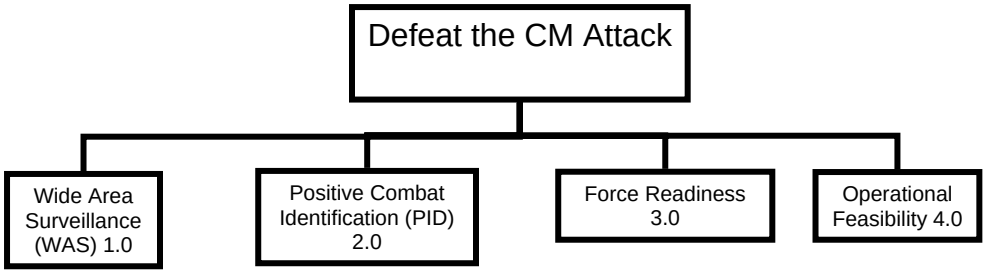

Figure 2. Objectives Hierarchy, Top Level Function

a. Wide Area Surveillance

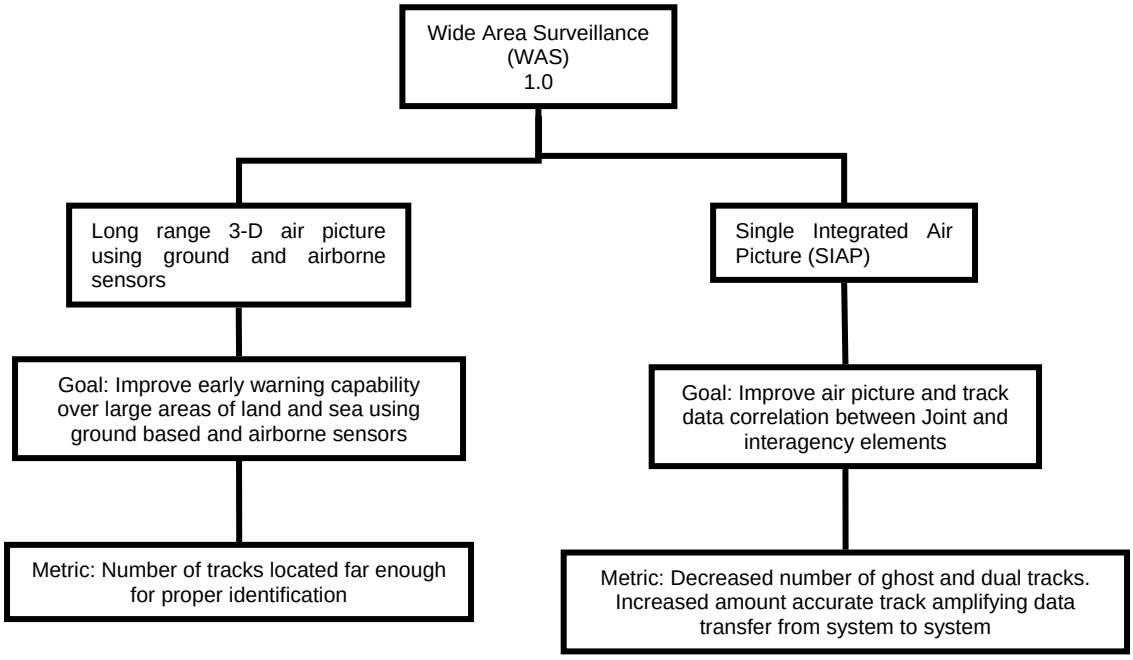

Figure 3. Objectives Hierarchy, Sub-function Wide Area Surveillance

The first important aspect of combating a CM threat is the systems' ability to detect and track a possible threat. Given the cruise missile's ability to launch from a low profile platform and maneuver below upward looking sensors, it is critical to establish a system with multiple sensors both ground based and airborne which are capable of constant surveillance around North American territory. Another important feature is that the airborne and ground based sensors produce a Single Integrated Air Picture (SIAP) in order to communicate and correlate common track data without producing false and dual tracks.

b. Positive Combat Identification

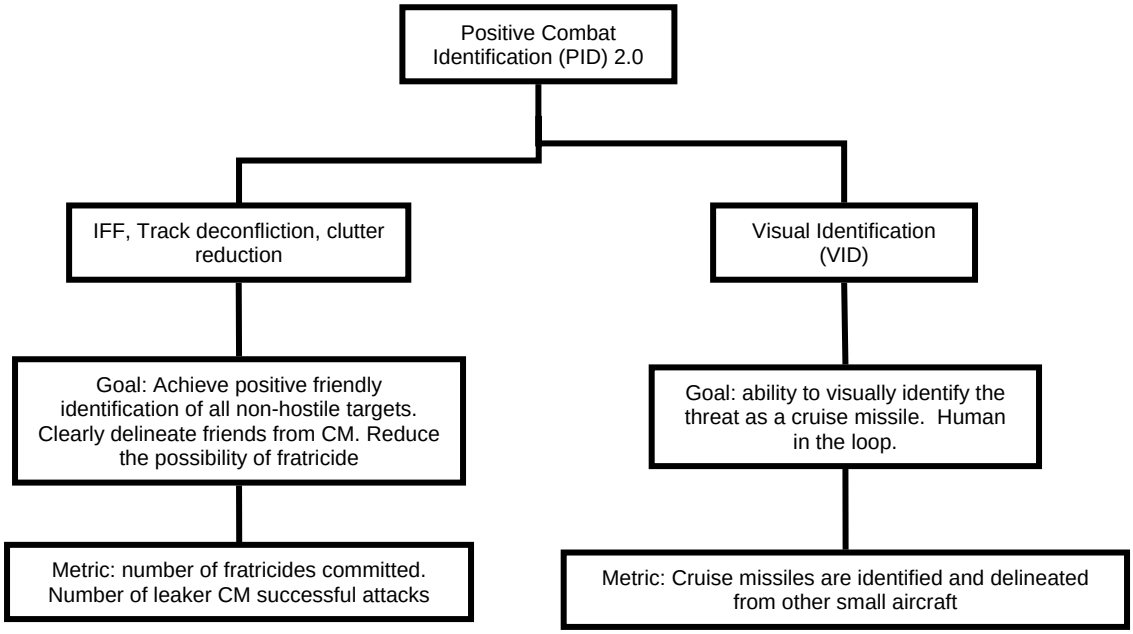

Figure 4. Objectives Hierarchy, Sub-function Positive Combat Identification

Once a possible TOI is located, it is critical to assign an identification as a friend or foe track. Since the U.S. is typically not a combat theater the amount of normal friendly commercial and private air traffic is greatly increased. Therefore, it is important for the system to be able to delineate normal air traffic from potential hostile tracks, by positively identifying friendly tracks in order to reduce the clutter of a SIAP. Furthermore, when committing to the possible engagement of a CM over U.S. soil it is even more important to be able to visual identification of the track to ensure that it is not mistaken for a smaller friendly, private aircraft.

c. Force Readiness

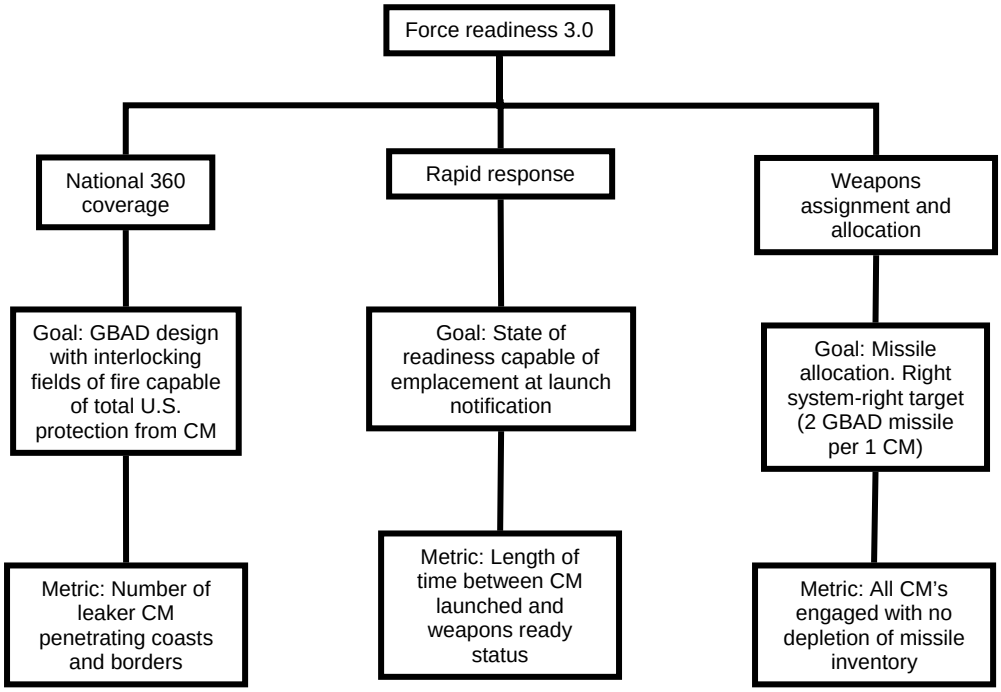

Figure 5. Objectives Hierarchy, Sub-function Force Readiness

Whenever possible it is important to have the right force, assigned to the right mission, at the right time and place and with the right equipment. When it comes to the security of the nation, every human soul should hold the same value for protection as every critical asset. The ideal system would have the ability to provide full, 360 coverage of the nation from CM attacks outside our coasts and borders. Ideally the system should be capable of the most rapid response by providing a GBAD posture that is concurrently at a high state of alert. In cases of accurate and actionable intelligence or NSSE's, the system will provide for a force that is pre-designated to the right mission, at the right time and place and with the right equipment. And finally the system should provide for the overwhelming destruction of the CM with a defensive missile inventory capable of expending two U.S. missiles per every one CM.

d. Operational Feasibility

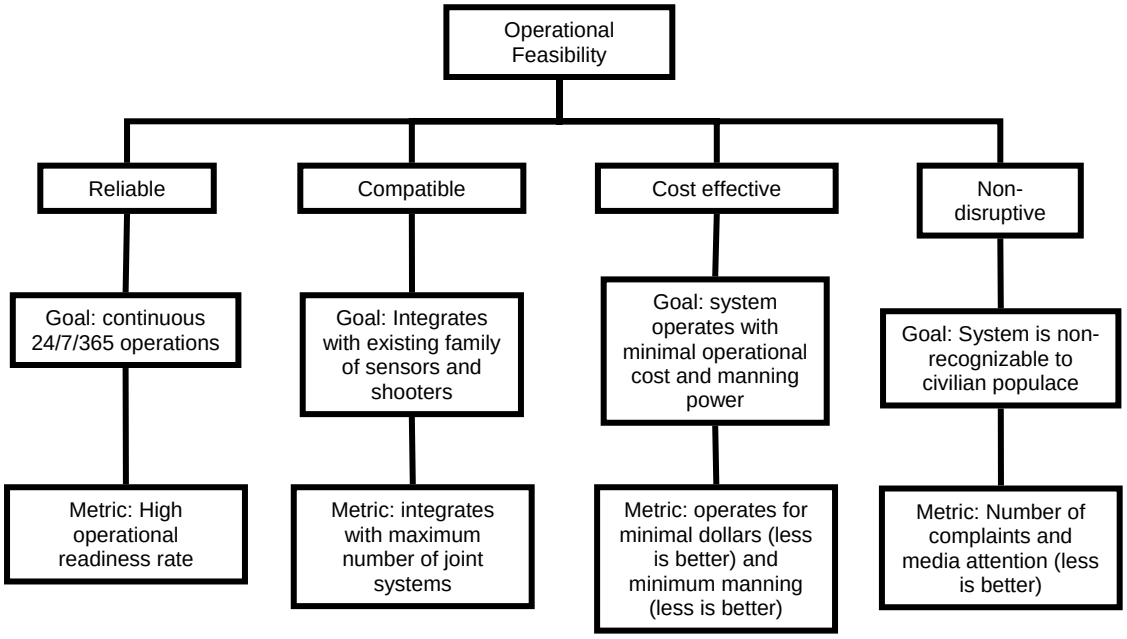

Figure 6. Objectives Hierarchy, Sub-function Operational Feasibility

The optimal GBAD system will be reliable, have redundant communications and maintenance procedures which allow for 24/7/365 continuous operations in all types of conditions. The GBAD system should be compatible with other sensor and shooter systems and be capable of full time operations in a joint environment. The GWOT is a war without an end in sight. Therefore we will assume that any GBAD system designed to provide for the CM defense of North America will need to be permanent. The ideal system will be a cost effective system that will require a low amount of actual crews actually operating and maintaining the equipment. The system should be capable of being operated out of existing C2 nodes established for HLD. Finally, the system should be as non-disruptive to the civilian populace as possible. Optimal emplacement of the system should be such that it does not intrude on privately owned land or public access areas.

H. CURRENT DEFENSE DESIGNS

GBAD coverage in phase three “Defeat” can be utilized to provide two general types of air defense; point defense and area defense. Point defense is

designed to protect specific critical and geopolitical assets. Area defense is designed to provide a general scanning capability over broad areas of terrain.

1. Point Defense

Point defense is a specific type of defense designed to protect specific critical or geopolitical assets from air threats along specific Air Avenues of Approach (AAA). The concept of operations for the GBAD point defense is to provide a "last line" of defense to protect specific assets, as well as the defending force, from all types of air threats. This type of defense is adequate for both critical assets and high profile events. This concept only provides defense for the populace which may, by chance occupy the surrounding areas near the specific defended assets. Successful employment of this concept requires actionable intelligence about a known and likely threat and may require a reasonable amount of time to emplace (24-72 hours).

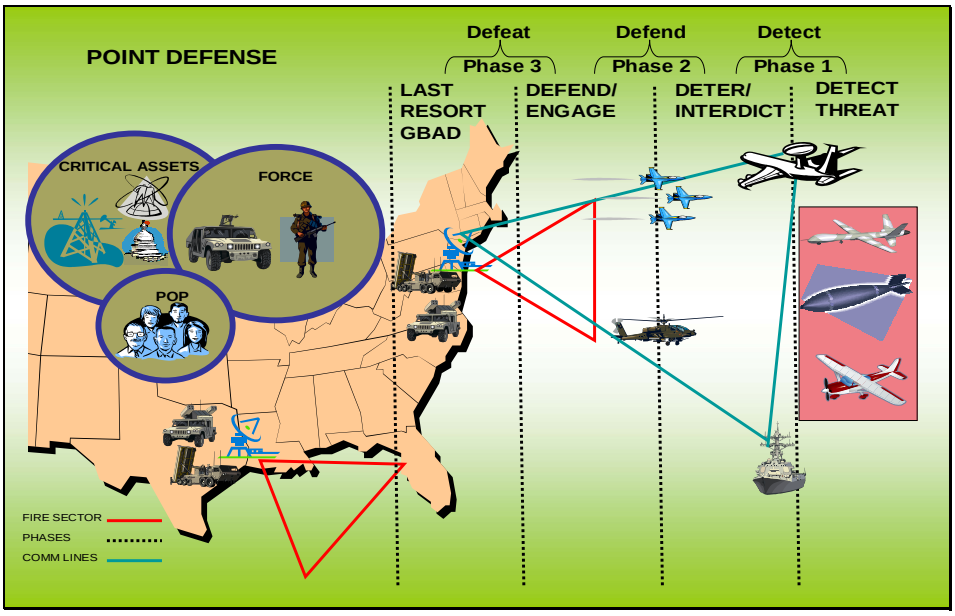

Figure 7. Point Defense

This type of point defense is adequate if the enemy intends to continue to attempt efforts of mass devastation and destruction designed to impact the daily operations of major sections of the U.S. by taking out key financial, military, political or energy assets. Point defense is ideal for critical assets and planned NSSE's.

2. Area Defense

Area GBAD is a concept designed to provide interlocking fires over vast amounts of terrain utilizing both sensor and shooter resources in order to provide protection from all types of air threats. This system is more expansive than point defense and it is designed to protect against a more random threat. This concept provides for a greater degree of protection to the U.S. populace. Area defense is not designated to specific critical assets but may consequently provide protection for assets which are located within the design. In addition the force protection provided by area defense would also be limited to the coincidental location of such forces. The area defense design could also augment the sensor and shooter capabilities of point defense resources.

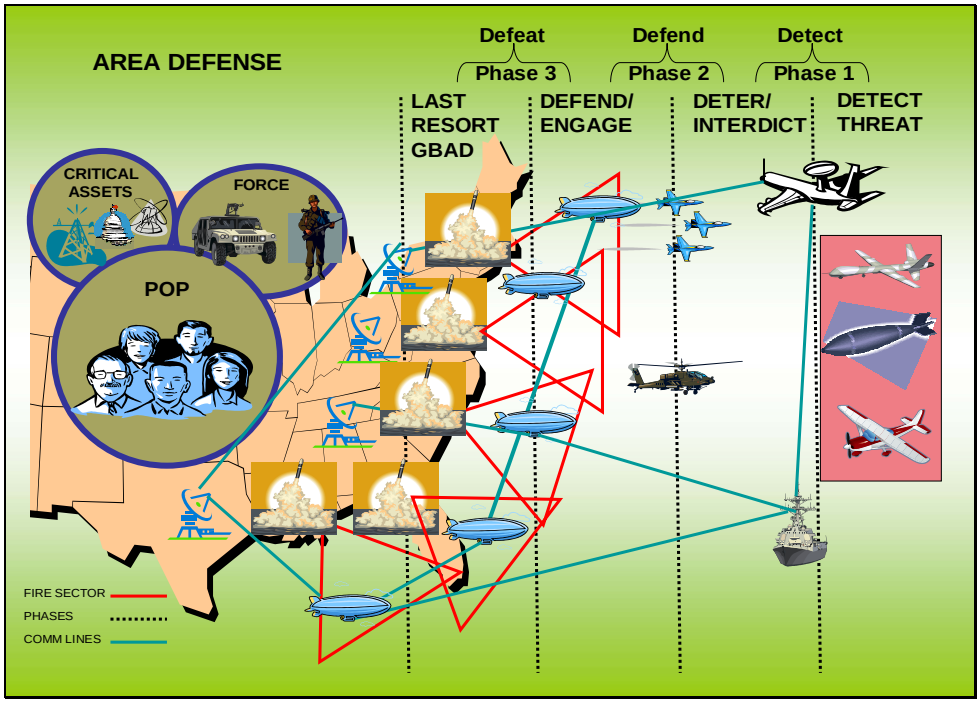

Figure 8. Area Defense

The U.S. has a passive capability to provide area defense based on good intelligence and ability to interdict, intercede and engage a threat prior to launch of the attack. We have an active capability to provide point defense for critical assets based on the prospect of good intelligence and our ability to intercept,

intercede and engage the threat before and after launch due to designated air and ground sensors, Combat Air Patrols (CAP)'s and a formidable GBAD.

III. MODELING ANALYSIS

Developing a strong CM defense system requires that two critical criteria are met. The employment of an optimal system should support the defense of critical assets and the general populace equally. As stated before, the GBAD role in point defense is specifically designed for the protection of critical assets and special events, but does not adequately cover areas surrounding the general populace. GBAD augmentation in area defense could provide an equal amount of CM defense across the coastlines and borders which encompass both critical assets and the general populace. In this chapter we will use game theory to prove that GBAD is an important element that strengthens a point defense to such an amount that it makes critical assets a non-favorable target for terrorist air strikes. We will demonstrate that adding a viable GBAD system to an area defense posture will provide the same results for terrorists who may wish to strike more random areas of the U.S. However, a strong CM defense can not be a complete defense by merely including GBAD systems in an area defense design. Such a defense needs to incorporate systems which are capable of meeting the objectives outlined in chapter II; wide area surveillance, positive combat identification, force readiness and operational feasibility. We will evaluate three GBAD systems (current, proposed and conceptual) and rate them according to their ability to meet these objectives. Our emphasis in scoring these systems will favor that which provides the best defense for critical assets and the general populace from a no-notice CM threat. The total CM defense system is one that is properly employed and includes the requisite capabilities to detect, defend and defeat the CM threat.

A. DEFINING THE GAME

In this chapter we present an analytical framework utilizing the Game Theory methodology describing concurrent choices by two adversaries – United States vs. Terrorists – in a conflict situation. Game theory will provide a basis for each participant to decide what strategy to utilize. The game will be played simultaneously employing a primary competitive strategy for each player with no

opportunities for cooperation. The gaming matrix will be formulated, as modeled in Philip Straffin's Game Theory and Strategy, as a constant sum equivalent to a two-person zero-sum game.[19] A zero-sum game is one in which the payoffs for the two players under any strategy pair sum to zero; that is when one player wins, the other loses.[20]

B. QUESTIONED TO BE ANALYZED:

As the U.S. continues to focus on building a strong air defense around critical assets and infrastructure, will the terrorists shift their strategy of committing air attacks on critical assets to attacking less well fortified targets in order to achieve a higher probability of a successful terror strike?

C. THE PLAYERS

Terrorists are non-state actors who are not bound by government rule, general military rules of engagement or military law. Given this circumstance the terrorists may choose to apply strategies that do not coincide with conventional combat tactics. The terrorists may choose to continue to use airborne vehicles as weapons in order to target critical U.S. assets. If the terrorists assume that the U.S. will increase their air defense posture around critical assets to thwart that strategy, they may deem that strategy as too risky and seek a new strategy. The terrorists may assume less risk in attempting to attack softer and less well defended targets in random areas along the U.S. coast and borders and thereby assume the probability of better success in engaging softer targets.

The U.S. can continue to build a robust air defense posture around critical assets under the assumption that the terrorists will continue to choose a strategy of damaging the U.S. major financial, military and energy resources by way of air attack. The U.S. may also assume that the terrorists may adapt to a formidable point defense around critical assets and thereby deem it too risky to attempt to attack a target with little to no likely payoff. This could lead the U.S. to assume that the terrorists may achieve a higher payoff by executing a successful attack

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[19] Philip D. Straffin. *Game Theory and Strategy.* The Mathematical Association of America. 1993, 65-67

[20] Daniel H. Wagner, W. Charles Mylander, and Thomas J. Sanders. *Naval Operations Analysis*. Naval Institute Press. 1999, 47

on smaller targets thereby achieving a less payoff with less risk of failure. In response to the terrorist's adaptive strategy, the U.S. could choose to build a robust GBAD which covers larger areas and provides an in depth air defense coverage in support of air assets providing air defense of the larger regions along our coasts and borders.

D. PLAYERS STRATEGIES

The below Strategy Matrix indicates the rankings given to both player's respective strategies based on their intersecting outcomes. The matrix has been given a scale of 1 to 4, with 4 being the most preferred and 1 being the least preferred ranking strategy each player would choose to take. Of note, each player is not given the opportunity to know beforehand what strategy the other player would choose. Therefore, each player has chosen its best strategy to take in order to achieve the stated objective as described below in Figure 9 for reaching a high probability of success.

		Terrorists	
		C – Critical Assets	**D** – Random Strikes
U.S.	**A**	AC (**4, 1**)	AD (**1, 4**)
	B	BC (**3, 2**)	BD (**2, 3**)

Figure 9. U.S. / Terrorists Strategy Matrix

Player I – U.S. strategies

A – In-depth active air defense posture establishing "point" defense for designated critical assets.

B – Several pod-like defense resources establishing "area" defense with interlocking fields of fire for the general populace along U.S. borders and coastlines.

Player II – Terrorists strategies

A – Execute attacks on critical assets, National Security Special Events (NSSE).

B – Execute random attacks on soft targets, e.g., general populace, schools, malls, etc…

1. Point Defense

AC ⟶ U.S. establishes a Point Defense with a multi-tier AMD posture that includes dedicated GBAD resources; Terrorists will attempt to strike critical assets within U.S. territory.

AD ⟶ U.S. establishes a Point Defense with a multi-tier AMD posture that does not include GBAD resources; Terrorists conduct random strikes against specific soft targets identified as having significant value/impact.

BC ⟶ U.S. establishes an Area Air Defense that includes a proposed deployable GBAD resource available to support U.S. mission directive (NSSE). Terrorists will attempt to attack critical assets or events on U.S. soil.

BD ⟶ U.S. establishes an Area Air Defense that has no GBAD resource available to support U.S. mission directive (NSSE). Terrorists conduct random attacks against specific soft targets identified as having significant value/impact.

2. Values Assessment of Both Players Strategies

AC: (4, 1) = If U.S. assumptions are correct in assessing that Terrorists will continue to strike critical assets, then the additional element of GBAD resources has the greatest value by providing an additional "last line" of Air Defense against a CM attack. Therefore, we assigned the greatest payoff (4) to the U.S. and the least payoff (1) to the Terrorists - AC strategy.

BC: (3, 2) = If the Terrorist choose to attack critical assets from the air then U.S. Air and proposed GBAD resources will be allocated to provide AMD against a CM threat. Therefore, we assigned the second greatest payoff (3) to the U.S. and the second least payoff (2) to the Terrorists - BC strategy.

BD: (2, 3) = If the Terrorists shift their strategy to conduct random strikes against specific soft targets within the U.S., the U.S. AMD posture does not incorporate a "last line" GBAD to defend against a no-notice CM strike. Therefore, we assigned a lower payoff (2) to the U.S. and the second greatest payoff (3) to the Terrorists - BD strategy.

AD: (1, 4) = If the Terrorists alter their strategy to conduct random strikes against non-specific soft targets in the U.S., there is no proposed GBAD in the AMD posture to defeat the CM attack. Therefore, we assigned the lowest payoff (1) to the U.S. and the greatest payoff (4) to the Terrorist - AD strategy.

3. United State's Supplementary Strategies

It is important to acknowledge that strategies "BD" and "AD" do not implicate a complete lack of CM defense, but rather a lack of the last line GBAD defense to augment the AMD posture surrounding the nation. The U.S. does employ air and maritime operations which incorporate both sensor and shooter assets capable of defeating a CM threat if given proper actionable intelligence and enough time to locate and identify the threat. NORAD has a continuous cycle of Combat Air Patrol's (CAP) which are capable of engaging air threats when they are aware of their location and intent. For purposes of this thesis we will only be analyzing the strategies (using them in the gaming payoff matrix) from the perspective of employing GBAD to provide a "point" and "area" defense, as described in chapter II of the current defense design.

E. THE GAME OF THE STATUS QUO

Based on the assumptions and the strategies depicted for each of the two players, the game develops as represented by the payoff matrix presented in Figure 10. In this particular matrix, both players' payoffs (the Row player being the U.S. and the Column player being the Terrorists) have been given independently to one another. That is, when the U.S. gains the Terrorist loses, and vice versa; with 4 being the best and 1 being the worst. Therefore, since the two players' payoffs are independent of each other it will be assumed that each player bases his own decisions on his payoffs alone; thus, drawing conclusions on the bases of the concept known as the Principle of Rationality, meaning every player wishes to come out as well off as possible.[21]

[21] Saul Stahl. A Gentle Introduction to Game Theory. American Mathematical Society, 1999 v. 13.

		Terrorist Action	
		C. Atk Critical Assets	D. Random Strikes
U.S. Action	A. Pt. Defense	(4 , 1)	(1 , 4)
	B. Area Defense	(3 , 2)	(2 , 3)

Figure 10. U.S. vs. Terrorists Action Matrix

As a result of the expected payoffs, it is determined that a Nash Equilibrium exists with the implementation of Strategies B and D, where the U.S. chooses the approach to establish an Area Defense for smaller, softer assets, against the Terrorists action of choosing to execute attacks on random soft targets (less defensible areas, e.g., populace, schools, malls, etc), having a payoff of (2, 3). In this particular gaming matrix, in which no communication is occurring between both players, the Nash Equilibrium sets at strategies BD indicating that neither player can freely improve their position unilaterally.

This approach taken from each player indicates the likely outcome when decisions are made without communication, thus, representing the status quo. More importantly, this strategy of attack taken from the Terrorists player illustrates a higher expected payoff probability; an approach that may offer a higher probability of success. Given the concerted efforts set by the U.S. to concentrate their AMD resources around critical assets, it is reasonable to assume that the terrorists will alter their strategy of attacking large critical assets to softer target strikes in which the U.S. AMD counter measures may be less robust or non-existent.

By implementing GBAD that is capable of protecting critical assets as well as the overall general populace into our HLD strategy against a terrorist random strike strategy, as Figure 11 below depicts, we can reduce the likelihood that terrorists will execute a successful CM strike on the U.S. A depiction of the players Security Values and Maximin and Minimax strategies have been described in detail in APPENDIX D and E.

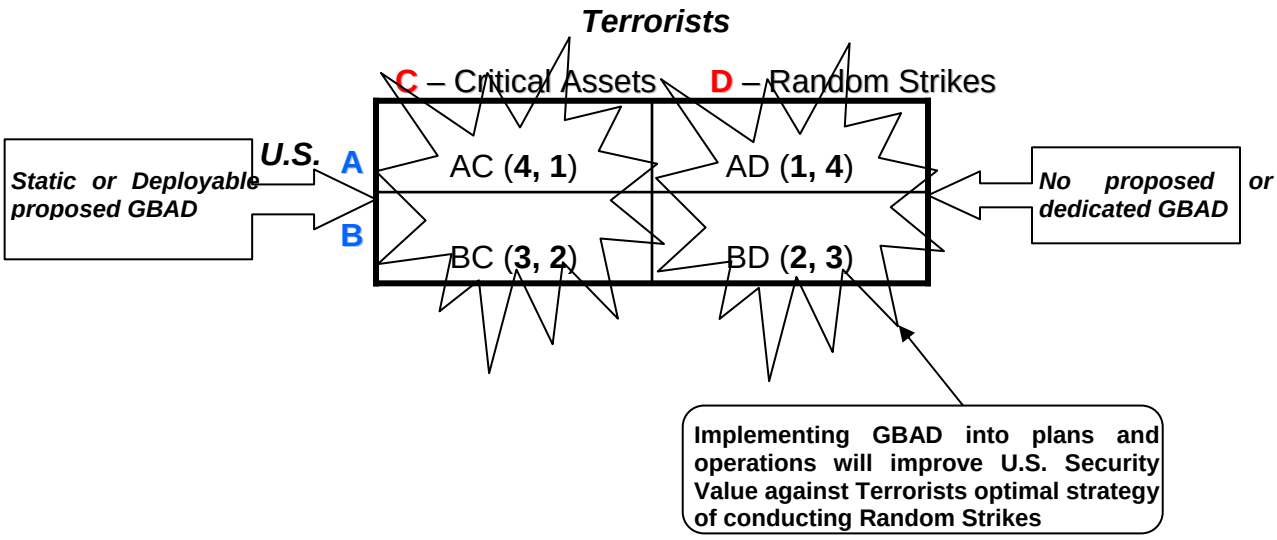

Figure 11. GBAD illustration / emphasis

F. ALTERNATIVES GENERATION

In determining the alternatives for GBAD systems designed to defend the nation against a CM attack we have conducted research on three pre-existing, viable alternatives. The first is the Joint Air Defense Operations Center (JADOC) which currently supports the N/NC HLD with GBAD in the National Capital Region (NCR). The JADOC is currently funded and operational. Secondly, we looked at the Joint Air Defense Operations- Homeland (JADO-H), which is a concept designed to support the DHACMD mission for N/NC. JADO-H is a concept that is currently under review by the Office of the Secretary of Defense (OSD) for approval and funding. The final alternative system we look at is the Low Cost Interceptor (LCI) program, which is a concept designed to provide full time, 360 CM defense coverage in support of HLD. LCI is a concept design which is not currently funded for fielding. We measure the capabilities of these alternatives against the metrics outlined in the needs analysis to defeat a CM attack, which are wide area surveillance, positive combat identification, and rapid response. We then measure the systems against the operational feasibility requirements, which include reliability, compatibility, cost effectiveness and non-disruptiveness.

1. JADOC

The JADOC is a HLD resource designed to detect, track, identify any possible enemy air threats directed at the NCR, and if necessary, engage such threats with military force. Command and control for the JADOC falls under the command of NORAD's Continental U.S. Region (CONR). The JADOC is comprised of U.S. Air Force and Army service members working in conjunction with one another to collaborate information from their respective services sensors and shooters to conduct track correlation, deconfliction and command and control. Operators can track information from a family of Federal Aviation Administration (FAA), as well as military ground based, elevated and airborne sensors and Electric Optical/ Infrared (EO/IR) cameras. GBAD operational responsibility in the JADOC belongs to the 263rd AAMDC, National Guard (NG). The JADOC is a static asset designed to protect critical assets in the nation's capital. They have a strong, multi-tiered capability to quickly elevate their alert status to detect and engage enemy air threats using fighter jets and Short Range Air Defense (SHORAD) weapons systems such as the avenger and AMRAAM variant missile systems. JADOC operations rely on the use of limited and restricted fly zones around the NCR. GBAD systems in the JADOC Area of Responsibility (AOR) maintain a 24/7/365 capability to provide point defense of designated critical assets. The system requires limited and/or full manning, depending of the state of alert, to operate properly. Figure 12 provides a general (not to scale due to classification) depiction of air defense coverage in the NCR.

Figure 12. Example of JADOC air defense coverage[22]

The JADOC is an optimal system for deterring and defeating hostile aircraft threats in the NCR. However, this system relies heavily on ground based and elevated sensors which are upward and outward looking. While this is more than adequate for detecting high flying aircraft, the CM may pose a greater challenge to these sensors. The 2006 Lincoln Lab Study showed a baseline performance in an urban defense environment against a CM for both fighters and SAM's to be poor or inadequate, though it should be noted that the performance for declared threats or hijacked aircraft to be good or adequate.[23] The study also demonstrated that the augmentation of downward looking sensors such as the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS), not improving the performance for the fighter jet, improved the GBAD performance from poor to adequate.[24]

2. JADO-H

The JADO-H is a system concept intended to utilize the capabilities of GBAD weapons systems and sensors, which have already been fielded, and

[22] Picture from USASMDC/NORAD JADO-H Joint Test and Evaluation, nomination briefing working version 16.0. Retrieved from SMDC Future Warfare Lab on16 November 2006

[23] L.O. Upton, MIT, Lincoln Labs, 2006. Slide 17

[24] Ibid. Slide 18

tailor their CONOPS to support the D-HACMD mission. JADO-H would employ such shooter systems as the Avenger, SLAMRAAM, and Patriot missile systems. This system can be used for two essential functions. First the JADO-H could be designated to provide GBAD support in emergency or critical air emergency situation. For JADO-H to be functional in this scenario it would require timely and actionable intelligence of a known or declared threat. Additionally JADO-H would have to have previously determined areas for emplacement of the system. Secondly, this system is ideal for NSSE's and/or even multiple, simultaneous NSSE's. Figure 13 is an example of the JADO-H, NSSE deployment capability.

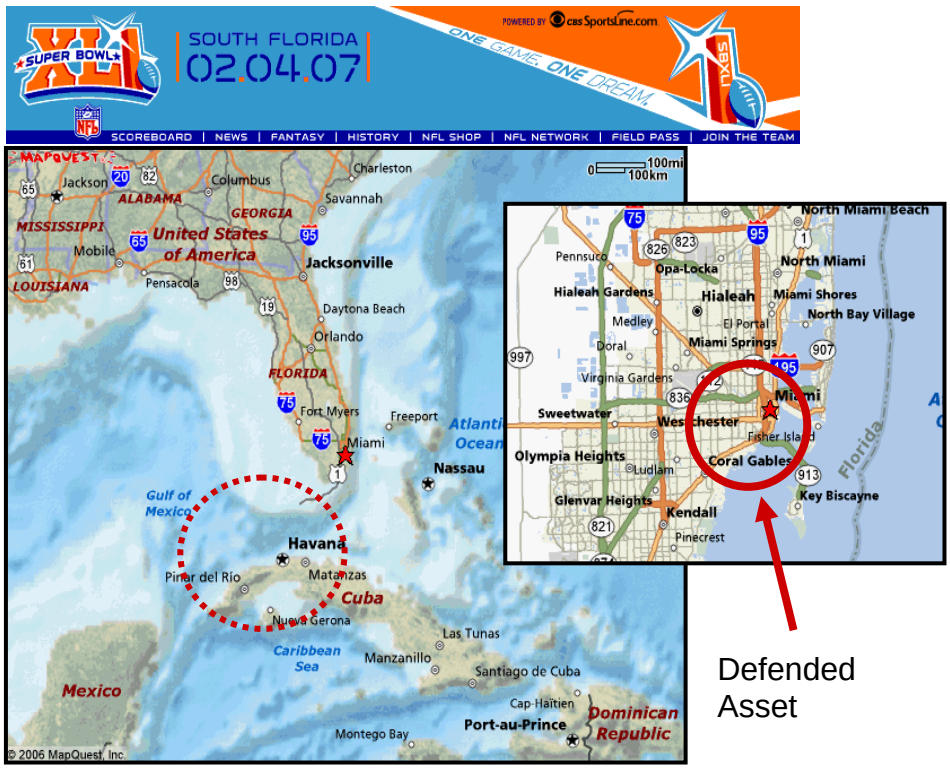

Figure 13. JADO-H deployed to provide CMD for Superbowl[25]

An example of such a scenario took place in June of 2004, when Ronald Reagan's funeral occurred at the same time as the G-8 summit, both on U.S. soil. The JADO-H concept, like the JADOC, is designed for point defense of

25 Picture from USASMDC/NORAD JADO-H Joint Test and Evaluation, nomination briefing working version 16.0. Retrieved from SMDC Future Warfare Lab on16 November 2006

specific, predetermined assets and requires a moderate amount of time for preparation and deployment of the system. Unlike the JADOC however, the JADO-H will utilize farther reaching sensors like the Relocatable Over The Horizon Radar (ROTHR) which provides high reliability and cost effective wide area coverage from 500 miles inland to 1,500 miles off the U.S. coastline.[26] Figure 14 portrays JADO-H wide area surveillance capability.

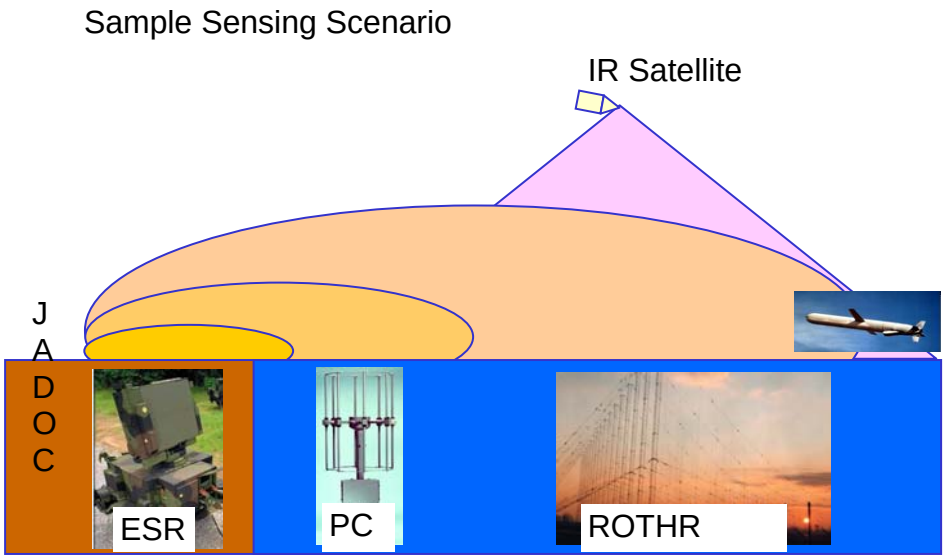

Figure 14. JADO-H Wide Area Surveillance Capability[27]

The JADO-H system provides an essential ability to counter the CM threat and link with and augment other joint and interagency sensors and shooters. The current JADO-H timeline proposes a material solution for 2015.

3. LCI

The Low Cost Interceptor is a concept design developed by SMDC's Technical Interoperability and Matrix Center (TIMC) as a CM (as well as other asymmetric air threats) defense system that optimally will provide 360 coverage of the U.S. utilizing several small missile silos spread across our borders and

[26] Raytheon brochure on ROTHR capabilities in support of Homeland Defense. Retrieved from SMDC FWC labs, Redstone Arsenal, AL. 16 November, 2006.

[27] Ibid.

coastlines. The weapons system will be compatible with existing sensor and shooter systems and will utilize JLENS and High Altitude Sensors (HAS) to achieve a downward looking Wide Area of Surveillance. The LCI system is capable of 24/7/365 operations and does not require constant manning to maintain and operate the system and can be operated out of one central C2 node such as NORAD or CONR. The LCI concept is system that is static, can provide area CM defense and can react to a CM threat in a manner of minutes once it is positively identified as hostile target. LCI's are a cheaper brand of missile and can be augmented by an even smaller variant, the Merlin. Each missile silo can hold 16 interceptors which are capable of engaging CM's. LCI and Merlin missiles are more maneuverable than standard Patriot and SLAMRAAM missiles. The concept design allows for silos-approximately 30-40 for total U.S coverage- to be emplaced in non-obtrusive government and publicly owned land and could currently cover about 80% of the U.S.[28] Figure 15 depicts and approximation of how the silos would be employed along the coasts.

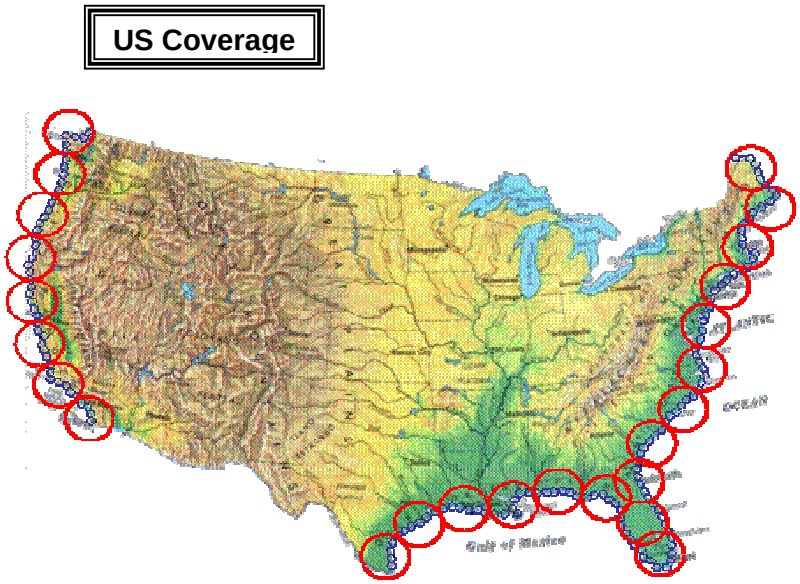

Figure 15. LCI Emplacement along U.S. Coastlines/Borders[29]

[28] Interview with LCI, program lead engineer Dave Tillson, SMDC, TIMC, Redstone Arsenal, AL. 16 November 06.

[29] TIMC "Efforts to Develop War Fighting Capabilities" Power Point brief. Received 16 November 2006.

Figure 16 demonstrates how the LCI could be employed in support of the homeland defense mission and how the system could be integrated with existing sensors and operated from one central C2 node.

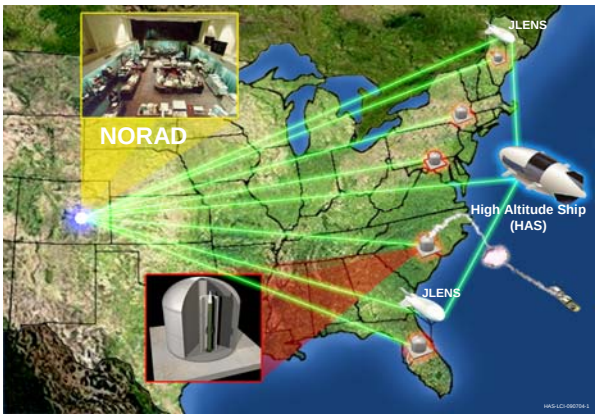

Figure 16. LCI in Homeland Defense Role[30]

G. SCORING

We will base the following scoring criteria, shown in Tables 1 and 3, on our assessment of the respective systems ability to detect, track, ID and engage the CM threat at a reasonable distance in a reasonable amount of time. This is our own assessment based on our research of the systems operational designs. Since some systems are not fielded we are not basing our research on empirical data or test results, but rather on the assumption that the systems sensors and shooters will operate as intended.

We use a scoring system of either, “Go” (G), or “No Go” (NG) to evaluate each alternative systems ability to meet the metrics outlined in the objectives hierarchy in chapter II. This is a simple three point system (0, .5 and 1) which assigns a G for a system that has the ability to meet the systems specific objective and a NG for a system that does not meet the objective criteria. A system with a limited ability to meet the objectives receives a G/NG. We calculate the scores with the highest score reflecting the system that is most optimal in meeting the requirements in the objectives hierarchy to defeat the CM attack in a “last line” defense role.

30 TIMC “Efforts to Develop War Fighting Capabilities” Power Point brief. Received 16 November 2006.

Operations	Current System JADOC	Alternative 1 JADO-H	Alternative 2 LCI
# of tracks ID as CMs located far enough for proper ID	NG	G	G
Decreased # of ghost & dual tracks, increased amount of accurate track amplifying transfer from system to system	G	G	G
# of fraticides committed. # of leaker CM successful attacks	G / NG	G	G
CMs are ID & delineated from other small A/C	G / NG	G	G
# of leaker CM penetrating coasts & borders	G / NG	G	G
Length of time between CM launched & weapons ready status	G/NG	G	G
All CMs engaged with no depletion of missile inventory	G	G	G
High Operational Readiness Rate	G	G	G
Integrates with maximum # of joint systems	G	G	G

Operates for minimal $ (less is better) & minimum manning (less is better)	NG	G / NG	G
# of complaints & media attention (less is better)	NG	NG	G
RECAP	NG	G	G

Table 1. Detail, Difference, and Impact of Systems

From a scale of 0 to 1, the following matrix below is the GO / NOGO score:

Assessment	Score
G	1
G / NG	0.5
NG	0

Table 2. Assessment/Score Matrix

Functions	Objectives	Current System JADOC	Alternative 1 JADO-H	Alternative 2 LCI
Wide Area Surveillance	# of tracks located far enough for proper ID	0+1 = **1**	1+1 = **2**	1+1 = **2**
	Decreased # of ghost & dual tracks. Increased amount accurate track amplifying data transfer from system to system			
Positive Combat ID	# of fratricide committed. # of leaker CM successful attacks	0.5+0.5 = **1**	1+1 = **2**	1+1 = **2**
	CMs are identified & delineated from other small A/C			
Force Readiness	# of leaker CMs penetrating coasts & borders	0.5+0.5+1 = **2**	1+1+1 = **3**	1+1+1 = **3**
	Length of time between CM launched & weapons ready status			
	All CMs engaged with no depletion of missile inventory			
Operational Feasibility	High operational readiness rate	1+1+0+0 =	1+1+0.5+0 =	1+1+1+1 =
	Integrates with maximum # of joint systems			

	Operates for minimal $ (less is better) & minimum manning (less is better)	**2**	**2.5**	**4**
	# of complaints & media attention (less is better)			
	RECAP (Total)	**6.0**	**9.5**	**11.0**

Table 3. Raw Data Matrix

The scoring data indicates that the current system (JADOC) scores lowest against the CM threat. There are several factors attributing this score, but it is important to reiterate that this system was not tailored around the CM threat and that it scores much higher against other irregular air attacks. Some of the primary reasons for the low score for the JADOC system are that most of its static radars are upward looking. Also, 24/7/365 operations require full time manning with crews to bring the system to operational status. Most of the shooter weapons systems for the JADOC are shorter range weapons and not designed to engage the CM threat from a distance. Finally the JADOC operates in an urban environment which limits its ability to engage CM's at low altitudes, and in some cases the weapons have been spotted locally and caused a stir in the populace.

The Deployable JADO-H scored second highest, because it was designed as the answer to the JADOC's issue of CM engagement. JADO-H has the long range surveillance capabilities necessary to detect and identify a CM in a timely manner which allows for a safe engagement. Two issues that hinder the JADO-H is that it is not designed to respond to a no notice CM threat. JADO-H requires time to be deployed to a specific asset and is designed for point, not area, defense. JADO-H is a great system for the CM defense of NSSE's. However, since NSSE's will be its most probable mission assignment it is not likely to avoid public attention.

The LCI system scored highest, because it meets the requirements of all sub-functions in order to successfully engage the CM threat. LCI had a wide area surveillance capability, it requires no actual manning and can be operated from a centralized C2 node. The system is designed to be compatible with all existing communications architecture. One of the best features of the LCI system is that it requires a minimum number of silos and can provide almost full 360 coverage of the U.S. without intruding on privately owned land. The overall best feature is that it is a system that will be ready to detect, identify and engage the no notice CM threat in a matter of minutes.

Our recommendation is to sustain the JADOC operations and continue to pursue the JADO-H system for NSSE support, but we recommend strong consideration for the LCI concept design as it is the system that is the most capable of providing a total U.S. CM defense and could be brought to FOC in time to meet the pending CM challenge.

IV. CONCLUSION

In this thesis we have examined one specific threat of many, which terrorists may choose to employ to bring harm to the U.S. The cruise missile threat is real and viable. We have demonstrated the characteristics of the CM which make it an attractive weapon for our enemies. CM's are small, fast, can fly under the scope of most ground based radars, and can be programmed to maneuver in and around terrain. While there are many barriers which could thwart a CM attack before it ever becomes a reality, our concern was focused on the idea that the terrorists may elude all first line detection efforts. Our concern was focused on the last line of defense which we have shown here to be the Ground Based Air Defense effort. Thus we have shown the need for an effective GBAD weapon system that can both detect the CM as well as match or outrun the CM capabilities.

We have illustrated that it would not be difficult for our enemies to acquire a low grade CM and to modify its navigational capabilities with off the shelf GPS technology. We have depicted a scenario portraying the method by which a terrorist organization could possibly bring a CM within range of the U.S. We know that if a CM does come within range of the U.S., and is capable of a launch, that we only have a matter of minutes to react. Therefore it is critical to have a weapons system that is capable of 24/7/360 vigilant surveillance. This system must be able to work with the entire family of joint and interagency sensors and shooters. Most importantly however, is the systems ability to react quickly to the CM threat and engage it outside of U.S. soil.

The Department of Defense as well as NORAD and NORTHCOM have recognized the reality of the CM threat and have taken steps toward implementing a GBAD system capable of countering the threat. Their current plans however, only plan for the shifting and redistribution of previously funded weapons systems. Current systems in place such as the JADOC provide good coverage against a declared or a hijacked air threat, but do not have a strong CM

capability. NORAD's Current proposed answer to that is the development of the JADO-H which will serve as an excellent resource for CM defense. However, both of these systems are only capable of providing point defense around critical assets or high visibility special events and do not cover the entire U.S. populace. While the JADO-H could tentatively provide CM defense anywhere in the U.S., it requires timely and actionable intelligence and would require time to deploy. If a CM leaker slips through the wire, there would not be enough time for the JADO-H to react.

Game theory has demonstrated that a rational planner who is seeking to launch a CM attack on the U.S. would not gain the level of success he would wish to achieve by attacking his normal high value targets, because he knows that this is what we expect and are planning for. Therefore, a rational actor will seek to gain a higher probability of success by attacking softer and less well defended targets in larger, more general areas of the population. This analysis proves the need for a stronger focus on a total area GBAD to support NORAD's air defense operations.

We have determined that for successful homeland defense against the CM threat there are four sub-functions which a GBAD system must perform. The optimal GBAD system should be capable of wide area surveillance, it needs be be able to positively identify the track as a CM, most importantly it needs to be able to provide a rapid response, and it needs to be feasible to operate and maintain. We have examined three alternatives for cruise missile defense in support of homeland defense and have made the following recommendation.

A. RECOMMENDATION

The JADOC system has a track record of proven success against critical air threats in the NCR. We would recommend no change in status to their current mission, but rather suggest that their support be augmented with a more robust GBAD CM capability. The 263rd AAMDC will have its hands full mobilizing National Guard Troops over the next several years to maintain and sustain

operations in the JADOC. Therefore allocating more manpower to support the operations of other systems could prove to be very taxing on the unit and the soldiers.

The JADO-H provides a good capability to augment NSSE's and critical air defense emergencies. However this system requires time to emplace and is not designed for the no notice threat. In addition, if the 263rd AAMDC is to cover the entire HLD mission for GBAD than they will have and even more difficult time fielding both the JADOC mission and JADO-H. In addition the JADO-H is not proposed to be Fully Operation Capable (FOC) until 2015 and if our threat assessment is correct the CM threat could be as little as five years away. We recommend pursuing the role of JADO-H in homeland defense but would add the recommendation of pre-designating missions to specific units. Build site data books for specific critical assets and events and train the service member and the systems to be prepared to deploy in support of their HLD missions.

In our estimation the LCI concept is a GBAD system which is capable of supporting all of the sub-functions we have deemed necessary for a viable CM defense against a leaker, or no notice CM threat. The LCI with its use of the JLENS sensors supports a wide area and downward looking surveillance of the coastal and border areas surrounding the U.S. The LCI is capable of 24/7/360 operations just as the JADOC and JADO-H. However, unlike the JADOC and JADO-H the LCI does not require the same amount of manning to perform its operations and maintenance. All manning for the LCI- as far as ID and shooter mode- can be conducted at the C2 node and maintenance can be periodically conducted with contractor support.

The LCI is capable of providing positive combat identification by sharing information and track amplifying data with sensors, such as JLENS which are already fielded. The most attractive feature of LCI as a CM defense system is its ability to react to the CM threat in minutes and not days. In all of our research this is the only conceptual system that provides protection from the no notice CM threat. In addition, it is the only system that provides close to 360 coverage of

the entire U.S. Although the LCI would likely be successful as a stand alone system, one of the major benefits would be its ability to augment existing air defense systems.

The LCI also met all of the feasibility requirements. Since the LCI is currently a conceptual system we assume some level of risk that it will be a completely reliable system other than to assume that the system will operate as proposed. We know that the LCI will use existing technology to be compatible with other sensor and shooter systems. The defense design of the LCI system allows for a reasonable number of missile silos to be place in unobtrusive areas throughout the country while still being able to engage CM's at a distance well outside U.S. territory. The LCI, by its very name, illustrates that the cost per missile is much less than that of most standard GBAD missiles. Although the LCI has not been funded for fielding, the senior analysts' estimate that the LCI could- if funded- be operational within two to three years, although we (the authors) assume risk in this assessment as the system has not been through the full Joint Test and Evaluation (JT&E) process. However if this estimate is true, the LCI could be capable of being operational prior to the most aggressive estimate about the enemies capability to execute a viable CM attack. Therefore we recommend that the LCI program be given due consideration to fund an operational JT&E and subsequently be funded for fielding in order to optimize the Ground Based Air Defense posture in support of the Homeland Defense mission.

APPENDIX A

to Optimizing Ground Based Air Defense Assets and Forces in support of Homeland Defense: The Cruise Missile Threat

A. U.S. WEAPONS CAPABILITIES

Below is a more extensive depiction of the U.S. existing GBAD weapons system capabilities, as well as research in emerging technologies and processes which may increase U.S. ability to help detect and defend its homeland against any future Terrorists cruise missile type attack.

1. Patriot Missile System

The Patriot missile is an advanced, lethal, long-range Air Defense system capable of detecting and destroying incoming enemy tactical ballistic missiles, cruise missiles, or advanced aircraft. Since the Gulf War in 1991, where Air Defense Patriot batteries first made their break-through performance by being heavily deployed and emplacing in areas of Kuwait and Saudi Arabia, consequently, resulting in significantly countering Iraq's Tactical Ballistic Missile launches throughout the duration of the conflict.

Over a decade later, Patriot missile batteries were tested once again by Iraq's Saadam Huessian forces in Operation Iraqi Freedom (OIF) to provide the critical services of shooting down enemy Scud missiles and protecting soldiers and civilians from a missile attack. In OIF, U.S. forces increased their Air Defense weapons capability by being equipped with a newly Patriot Advanced Capability (PAC-3) missile which significantly enhanced their effectiveness of engaging and destroying a number of hostile surface-to-surface air missiles (SSAM) launched by Iraqi forces.

The Patriot Air Defense Guided Missile System is designed to defeat the air threat of the 21st Century.[31] "The range of the missile is 70km and maximum altitude is greater than 24km. The minimum flight time is the time to arm the missile, which is less than 9 seconds, and the maximum flight time is less than 3 ½ minutes.[32]" The exceptional characteristics of the Patriot weapons system make it a self-reliant deployable system

Since its inception in 1981, the Patriot Air Defense missile system has been an effective, proven weapons system. Over the years, the missile system has seen continuous advanced developmental improvements, especially in its advanced hit-to-kill technology arena. The missile system is now featuring a sophisticated GEM+ missile which provides an upgraded capability to defeating cruise and ballistic missiles as well as air-breathing threats (ABT). In addition, with new technology advances, the Patriot missile system is now capable of having 16 PAC-3 missiles loaded onto a launcher as compared to four in the PAC-2 missiles configuration.

2. Stinger Missile System

The Stinger Missile system is an extremely accurate short-range Air Defense weapon for the U.S. Army forces. The Stinger missile is intended to give military ground forces an opportunity to counter enemy low-flying Air Breathing Threats (ABT) such as fixed-wing aircraft, helicopters, unmanned aerial vehicles, and cruise missiles. The missile features a quick-reaction

[31] Ground Based Air Defense – Patriot. Retrieved on 5 October 2006 from Ground Based Air Defense website: http://www.gbad.org/gbad/amd_patriot.html

[32] Army Technology – Patriot Missile. Retrieved on 9 September 2006 from Army Technology website: http://www.army-technology.com/projects/patriot/

acquisition and tracking engagement that uses an infrared seeker to lock on to the heat in the aircraft's engine exhaust, and will hit nearly anything flying below 11,000 feet.[33]

Some other distinct advantages that the Stinger missile has are such features as being a lightweight, mobile weapon. It is a shoulder-launched, fire-and-forget weapon, fired by one person, however usually operated by a two-man team. The Stinger missile has a 3kg high explosive fragmentation warhead, with a maximum speed of Mach 2.2.[34] The missile launcher is reusable and weighs about 35 pounds. Additionally, the missile system uses a passive infrared seeker to engage its target, dissimilar from a radar guided missile that emits radio waves in order to identify its target.

Essentially, Stinger missiles can engage targets flying as high as 11,500 feet with a range of about 5 miles (8 km). Consequently, if an enemy aircraft is less than 2 miles high and is visible to the ground troops as a shape, rather than a dot, then it is likely that the Stinger missile system will successfully acquire a confirm kill.[35]

The tactics used by terrorists on September 11, 2001, high-jacking commercial planes to attack the United States in New York, Pennsylvania, and Washington, D.C. have since drastically revitalized the Missile Defense focus on utilizing the Stinger missile to counter such a threat, if employed again by terrorist.

Operationally, low-flying enemy aircraft are typically a dilemma, posing an extreme threat factor for ground forces, consequently, performing operations such as dropping ordinance or strafing, conducting reconnaissance –

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[33] Marshall Brain. "How Stinger Missiles Work," Retrieved on 6 September 2006 from How Stuff Works website: http://science.howstuffwoks.com/stinger.htm

[34] Army Technology – Air Defense Missile Systems. Retrieved on 7 September 2006 from Army Technology website: http://www.army-technology.com/projects/airdefencemissilesystems_gallery.html

[35] Brain

surveillance work or inserting, extracting and resupplying enemy forces. Simply employing the Stinger missile to destroy these ABTs is the easiest way to remove the threat.

3. Avenger Missile System

As part of the Stinger weapons system, the Avenger is an Air Defense missile system designed to destroy enemy low-altitude and high-speed fixed or rotary-wing aircraft. The system is a nimble light-weight, day/night, portable fire unit. The missile system functions from a pedestal mounted High Mobility Multi-purpose Wheeled Vehicle (HMMWV) chassis and carries eight heat-seeking Stinger missiles inside two rapidly re-loadable pods mounted either side of the turret. These pods have a range of elevation from -10 degrees to + 70 degrees with a missile reload time of eight missiles in less than four minutes.[36]

During OIF, the Avenger missile system provided critical protection to forward and rear U.S. forces, most importantly command posts on advancing ground troops up to Baghdad, throughout the duration of the war campaign. Moreover, with its mounted .50-heavy caliber machine gun (mainly used for self-defense), it can also provide protection to forces as it maneuvers into rocket firing position by suppressive fires. Essentially, the Avenger system presents an effective nimble forcible offensive/defensive front against enemy targets.

[36] Army Technology – Avenger. Retrieved on 9 September 2006 from Army Technology website: http://www.army-technology.com/projects/avenger/

4. SLAMRAAM Missile System

The Surface Launched Advanced Medium Range Air to Air Missile (SLAMRAAM) is the U.S. Army's future short range AD weapons system. The SLAMRAAM offers the Army an effective Air Defense protection capability against the emerging asymmetric aerial threats, cruise missiles and unmanned aerial vehicles (UAVs). The SLAMRAAM fire unit consists of four to six ready-to-fire AIM-120C-7 AMRAAMs mounted on an Army High Mobility Multi-Wheeled Vehicle (HMMWV).[37] The Raytheon AMRAAM AIM-120C missile is fitted with clipped fins that have a longer range (25 km intercept range) and a very high agility to counter targets making evasive maneuvers.[38]

Continuous software upgrades have been made to the AMRAAM missile system, such as the added command destruct/self destruct capabilities, essentially improving the missile's facility of intercepting cruise missiles and other unmanned aerial targets, over urban terrain. Ultimately, this future missile defense system will provide U.S. military forces a rapidly deployable, all-weather, high fire power, stand-off AD weapons capability in defeating enemy aircraft, CM and UAV's beyond the range of currently fielded Avenger and Stinger MANPADS fire units.[39]

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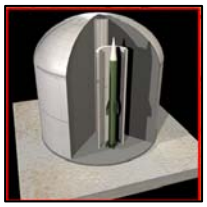
[37] Ground Based Air Defense. SLAMRAAM – Surface Launched Advanced Medium Range Air to Air Missile. Retrieved on 5 October 2006 from Global Security website: http://www.gbad.org/gbad/amd_slamraam.html

[38] Army Technology – Surface-Launched AMRAAM (SLAMRAAM/CLAWS) Medium-Range Air Defense System, USA. Retrieved on 5 October 2006 from Army Technology website: http://www.army-technology.com/projects/surface-launched/

[39] Ground Based Air Defense. SLAMRAAM.

5. Low Cost Interceptors (LCIs)



Low Cost Interceptors can be a significant cost-effective added missile system to Joint Cruise Missile Defense, Joint Warfighting. LCIs have a low cost requirement and are an addition to existing and future AD systems, namely to the PAC-3 and SLAMRAAM missile systems, therefore indicating a nominal logistical impact. Conceptually, LCIs will have a longer range capability (150 km intercept range) ultimately improving inherent survivability, sustainability.[40] Longer range of missile extends the Battlespace (20 to 150 km) allowing for flexibility, thus providing a greater in depth Area Air Defense coverage. Moreover, LCIs are capable of incorporating a Single Integrated Air Picture; fundamentally, designed specifically for use with Elevated Sensor and Integrated Fire Control Network-Centric systems on the Battlefield.[41]

Notably, one potential missile designed for countering a CM threat is from the Netfires Compatible Interceptor (NCI) for CMD and Homeland Defense in Huntsville, Alabama. The organization is currently demonstrating the Netfires Missile Launcher to the U.S. Army as a common launcher capable of being positioned and left independently at key locations throughout the United States. The Netfires launcher is intended to providing all functions necessary in a self-sufficient, autonomous mode unit.[42]

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[40] David Tilson. Low Cost Interceptor (LCI) Technology Integration Demonstration Program. Program Lead USASMDC, OTII. Presentation to North America Aerospace Defense Command. July 2004.

[41] Tilson. July 2004.

[42] David Tilson and Stephen Hutson. Netfires Compatible Interceptor for CMD and Homeland Defense. Army Space and Missile Defense Command, Aero Thermo Technology, Inc. Huntsville, Alabama, September 8, 2006.

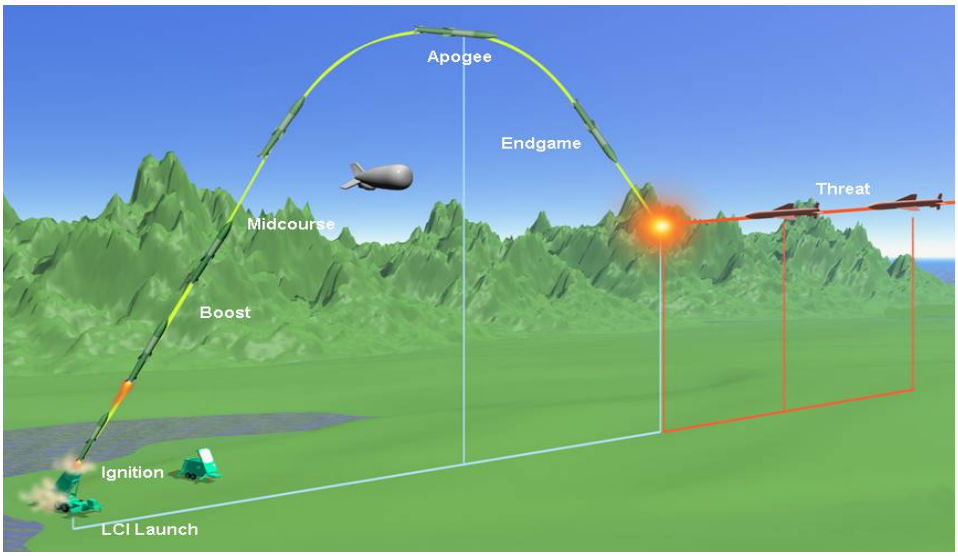

Figure 17. Typical LCI Mission[43]

[43] David Tilson. Low Cost Cruise Missile Defense (LCCMD), Home-on-Home, Army Space and Missile Defense Command, Huntsville, Alabama, July 18, 2006.

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APPENDIX B

to Optimizing Ground Based Air Defense Assets and Forces in support of Homeland Defense: The Cruise Missile Threat

A. TERRORISTS CM WEAPONS CAPABILITIES

Terrorists from rogue states are capable of building Cruise Missiles from available supplies of vast technological resources to attack the population sociable hubs and Critical Infrastructure sights of the United States. Below is some additionally information on the CM type Terrorists weapons of choice as discussed in the main thesis document.

1. Cruise Missiles (CM)

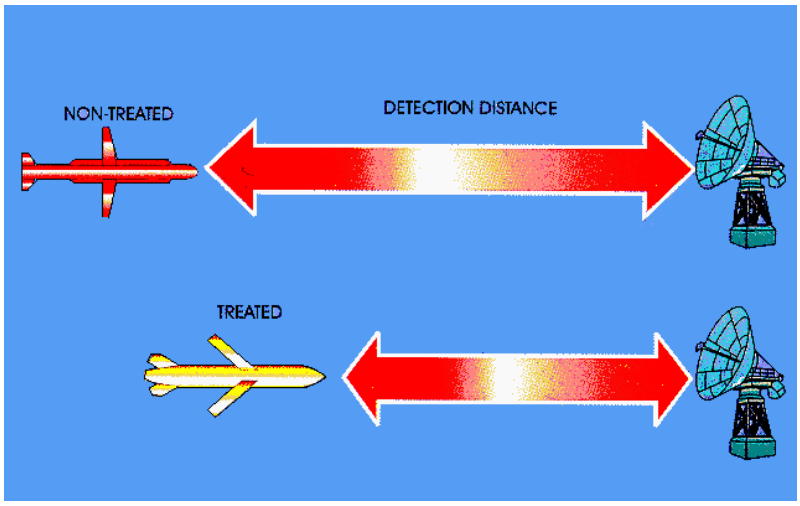

Cruise Missiles are essentially small turbofan engines used to cruise to their targets. CMs can take numerous trajectories; however, in general have two common flight patterns. "The first pattern is for the missile to climb after launch and cruise at high level, at between 10-20 km altitude, and then to dive down to low level, at 10-200 m altitude, before running into the target. The second pattern is for the cruise missile to fly at low level throughout the trajectory. The missiles can change direction several times during a flight, and can be programmed to attack more than one target.[44]"

As mentioned above, CMs can fly 500 to 1,000 mile (805 to 1,610 km) depending on the configuration and are very effective because they are very

[44] Jane's Information Group. Cruise Missile Defense. Retrieved on 5 October 2006 from the Jane's Information Group website: http://www.janes.com/defence/land_forces/news/jsws/jsws060927_1_n.shtml

difficult to detect, even with infrared detection, it still remains difficult because of the turbofan engines emitting little heat.[45]

CM's are inexpensive, easy-to-construct weapons that can be used to create shocking effect by terrorists, subsequently, could be employed as a WMD type threat. The cruise missile's sleek stability makes it a naturally easier and cheaper platform from which to carry out and scatter chemical and biological agents, giving it a lethality factor more than 10 times greater than that of a ballistic missile for a given amount of biological agent.[46]



A missile treated with radar-absorbing material is detected at shorter range, so Air Defense forces have little time to react.[47]

[45] Marshall Brain. How Cruise Missiles Work. Retrieved on 9 September 2006 from How Stuff Works website: http://science.howstuffworks.com/curise-missile.htm

[46] Michael C. Sirak and Daniel G. Dupont, "Expert: U.S. Not Prepared for Cruise Missile Attacks," *Inside Missile Defense*, 23 Dec. 1998, 5.

[47] Ballistic and Cruise Missile Threat. National Air Intelligence Center NAIC-1031-0985-98. Retrieved on 10 September 2006 from NAIC website: http://www.fas.org/irp/threat/missile/naic/part07.htm

APPENDIX C

to Optimizing Ground Based Air Defense Assets and Forces in support of Homeland Defense: The Cruise Missile Threat – The U.S. vs. Terrorists modeling conflict situation.

A. GAME THEORY TERMINOLOGY

In comprehending this methodology describe in our thesis, it is important to define certain terms used when applying game theory that will be helpful to the reader in understanding our analysis:

1. The payoff matrix of a game is the matrix wherein each row corresponds to a strategy of the maximizing player, each column corresponds to a strategy of the minimizing player, and the matrix entry is the payoff resulting from the strategy choices of that row and column.

2. A play of the game is the choosing of a strategy by each player, i.e., a row and column of the payoff matrix, along with the awarding of the payoff which results.

3. An optimal strategy for either player of a two-person zero-sum game is one which provides the best guarantee available to that player, i.e., a maximin strategy for the maximizing player or a minimax strategy for the minimizing player.

4. The value of a game is the guaranteed payoff for each player, providing it is the same for each and providing each uses an optimal strategy.

5. The solution of a two-person zero-sum game is an optimal strategy for each player and the numerical value of the game.[48]

6. Nash equilibrium, named after John Nash, is a set of strategies, one for each player, such that no player has incentive to unilaterally change their

[48] Daniel H. Wagner, W. Charles Mylander, and Thomas J. Sanders. Naval Operations Analysis. Naval Institute Press. 1999, 47

action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if the player remained with its current strategy.

7. A simultaneous game is one in which all players make decisions or select a strategy without knowledge of the strategies that are being chosen by other players. Even though the decisions may be made at different points in time, the game is simultaneous because each player has no information about the decisions of others; thus it as if the decisions are made simultaneously. Simultaneous games are represented by the normal form and solved using the concept of a Nash equilibrium.[49]

[49] Mike Shor. Game Theory Net. 2001-2006. Retrieved on 9 September 2006 from http://www.gametheory.net/dictionary/Equilibrium.html

APPENDIX D

to Optimizing Ground Based Air Defense Assets and Forces in support of Homeland Defense: The Cruise Missile Threat – The U.S. vs. Terrorists modeling conflict situation.

A. PLAYERS SECURITY VALUES

Having determined that neither the U.S. nor the Terrorists can improve by unilaterally moving from its dominant strategy, it becomes essential to analyze each player's game to determine if there is the possibility of improving an outcome by playing one side's game. Figures 1 and 2 show the results of both the United States' and Terrorists games. In each game, the objective is for the player whose game is being analyzed to maximize its outcome while the opponent attempts to minimize the other player's outcome. The end result determines each player's security value.

1. U.S. Game Options

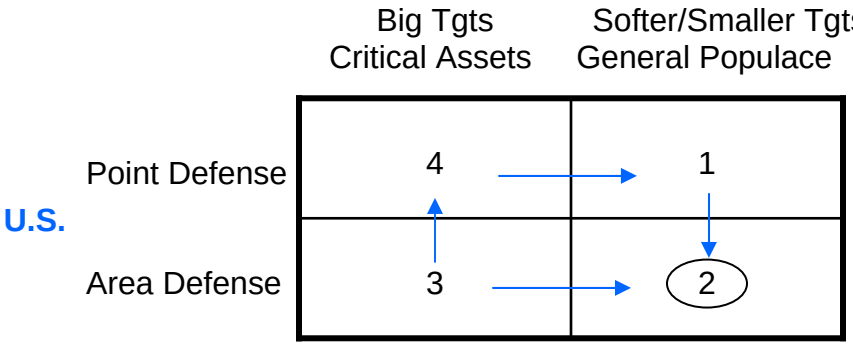


Figure 1: Viewing internal U.S. Game

U.S. objective – Maximize Outcome

Terrorist objective – Minimize Outcome

U.S. Security Value – 2

2. Terrorists Game Options

Terrorists

Big Tgts 65 Softer/Smaller Tgts
Critical Assets General Populace

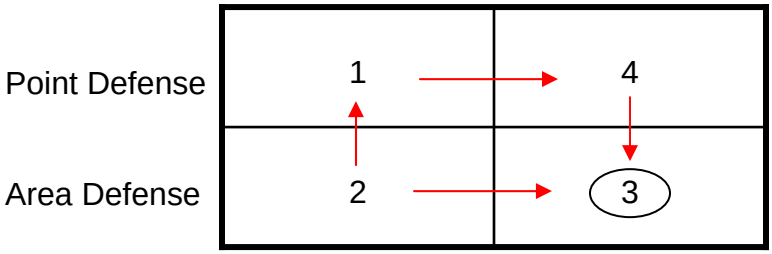


Figure 2: Viewing internal Terrorists Game

Terrorist objective – Maximize Outcome

U.S. objective – Minimize Outcome

Terrorist Security Value – 3

APPENDIX E

to Optimizing Ground Based Air Defense Assets and Forces in support of Homeland Defense: The Cruise Missile Threat – The U.S. vs. Terrorists modeling conflict situation.

A. PLAYERS MAXIMIN AND MINIMAX STRATEGIES

1. Analyzing U.S. Area Defense

U.S. employing an Area Defense strategy against Terrorists Random Strikes strategy (noting no current U.S. GBAD resources existing) focusing on "Defeat" the CM attack while utilizing the U.S. expected payoffs.

* A - AMD concentration around critical assets

* B - AMD concentration around general populace

		Terrorists Attack		
		Big Targets	Softer/Smaller Targets	
		C - Critical Assets	D - General Populace	
				min
	A – Point Defense	4	1	1
U.S.				***Maximin***
- Defeat	B – Area Defense	3	2	2 **2**
	max	4	2	

***Minimax* 2**

U.S. can assure a payoff of at least 2, his maximin, by choosing strategy B. Terrorists' best guarantee, his minimax, is 2, using strategy D. Hence, when the maximin and the minimax are the same, the resulting outcome is called a saddle-point. If a game has a saddle-point, it gives the value of the game and the optimal strategies for both players by yielding the saddle-point payoff (2 for

U.S. Area Defense and 2 for Terrorists to conduct random strikes on softer/smaller targets).[50] The value of the game together with its maximin and minimax strategies constitute the solution of the game.

Without knowledge of the Terrorist's strategy, a reasonable choice for U.S. is the maximin strategy, i.e., to employ an Area Defense concentrating on protecting the softer/smaller assets and guarantee a payoff of at least 2.

2. Analyzing Terrorists Attack

Terrorists instigating an attack against a limited U.S. Area Defense strategy (currently is not optimally implemented) focusing on achieving catastrophic, destructive and substantial damage to its adversary; utilizing its own expected payoffs.

* A - AMD concentration around critical assets

* B - AMD concentration around general populace

		Terrorists Attack		
		Big Targets	Softer/Small Targets	
		C - Critical Assets	D - General Populace	
				max
	A – Point Defense	1	4	4
U.S.				***Minimax***
- Defeat	B – Area Defense	2	3	3 **3**
	min	2	3	
		***Maximin* 3**		

Terrorists can assure a payoff of at least 3, his maximin, by choosing strategy D. U.S. best guarantee, his minimax, is 3, using strategy B. Once more, a saddle-point exists in this strategy match signifying a 3 for the value of the game. In this case, both players can guarantee at least this value by choosing their maximin and minimax strategies.

[50] Naval Operations Analysis, 49-50.

Without knowledge of the U.S. strategy, a reasonable choice for Terrorists is the maximin strategy, i.e., to attack softer/smaller targets and guarantee a payoff of at least 3.

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